JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

Vol. 38 SEPTEMBER 1946 No. 9

Contents

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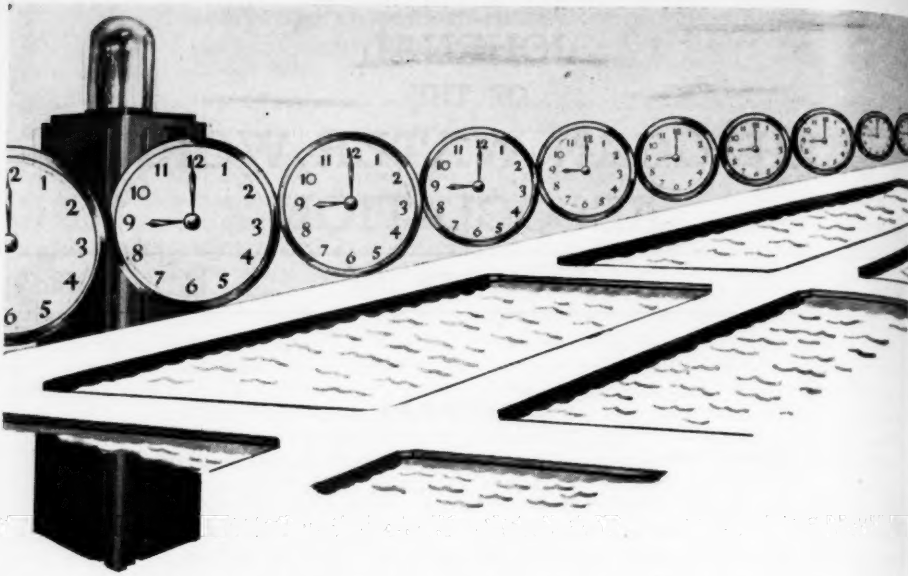

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AMERICAN WATER WORKS ASSOCIATION

Vol. 38 | September 1946 | No. 9

New Materials and Equipment for Water Works

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Presented on May 10, 1946, at the Annual Conference, St. Louis, Mo.

RAPID progress in the creation of new engineering materials and technical methods during the last few years has made a great impression upon the public. Many of these interesting new materials and applications of equipment and methods are now, or soon will be, available in the water works field for construction, system maintenance and operation, and for research. Enough is now known about innovations in valves, plastics, silicones, pressure welding, supervisory control systems and electronic laboratory devices to permit discussion of them.

Sleeve Valves

A new sleeve valve has been developed by the Pelton Water Wheel Company of San Francisco for use as a check valve, but indications show that it can be used for free discharge services as well as an altitude control valve. This valve is still in the experimental stages.

The peculiar construction of the valve, which has a rigid frame, permits it to be collapsed and lifted out of the framework without disturbing the pipeline itself. This overcomes the objection to the needle valve or Larner Johnson valve, the inside working parts of which can only be repaired after removal of the valve or a section adjacent to it. The new valve has a movable sleeve which slides with or against the direction of the water flow. The sleeve seats against a stationary needle bulb which is held in place in the valve by ribs. The sleeve is hydraulically balanced against internal water pressure by means of an external balancing chamber.

Valve Actuator

A valve actuator, designed to operate valves hydraulically and put on the market by the Pacific Division of the Bendix Aviation Corporation, has been specified for installation in the new steam power plant of the Los Angeles Department of Water and Power. Construction of the actuator is extremely simple. A reversible electric motor of comparatively small horsepower drives the oil pump in either direction and provides oil, under pressure, to be used in closing or opening the valve.

Pressure to close the valve is applied to the "close" side of the cylinder and, as the valve seats, this pressure is built up, literally pressure-sealing the valve. The pressure is then locked in the cylinder and only the reverse action will unlock it. When, for any reason, the pressure drops it is re-established automatically and immediately.

Valve Installation

One of the problems facing water works operators during the past four years has been the necessity of prolonging the useful life of transmission and distribution mains. The scarcity of pipeline material made it necessary to confine the use of new pipe largely to extensions for new business and the installation of new mains to meet the new business loads. This condition occasioned the use of comparatively new types of equipment as aids in deferring the replacement of mains that under normal conditions would have been considered beyond repair.

Two types of valves have been particularly useful in solving these problems. One extended the usefulness of a transmission main; the other reduced maintenance on booster pumping equipment in the system of the California Water Service Co., which serves areas near Los Angeles. Both valves are products of The Clayton Manufacturing Co. of Alhambra, Calif.

Pump Control Valve

Installation of a pump control valve was decided upon in order to control pressures in a 16-in. transmission main which was being subjected to some rather high surges, from time to time causing very serious main breaks. A pressure study revealed an overall surge of 120 psi., including positive and negative surges. From a static of 165 psi., pressure increased to 220 psi. when the pump was started, settling to a running pressure of 175 psi. Upon shutting down the pump, pressure dropped to 100 psi., then, over a ten-minute period, gradually rose, leveling off to the 165 psi. static.

Upon installation of the pump control valve, the maximum starting surge was held to a 5-psi. increase, and the negative surge on shutting down the pump was limited to 7 psi. Operation of this valve is controlled by a solenoid-operated pilot valve which functions to open or close the main valve. The pump starts against a closed valve and, as the solenoid is energized, it actuates the pilot valve to allow the main valve to start opening. Thus, as the valve gradually opens, pump pressure is, likewise gradually, applied to the line, eliminating the surges caused by the usual fast-operating check valves.

Closing action of the pump control valve is also gradual, as this operation is again controlled by the pilot valve which starts closing the main valve gradually. If the power should fail while the pump is running, there is no protection against surge, for a check valve assembly incorporated in the valve will close it instantly.

Modulating Float Valve

The modulating float valve was primarily intended to smooth out the operation of a booster pump and so to decrease maintenance on the electrical starting equipment operating the pump, but here too the valve helped eliminate surges on a transmission main. The supply to the booster pump is from a 7,200-gal. collection basin receiving water from two well pumps, one located on the premises, the other some 1,300 ft. distant. The booster discharges into a transmission main terminating in a 220,000-gal. standpipe situated 1,300 ft. from the booster station. Operation of the two well pumps and the booster is controlled by float switches in the collection basin as well as by a high- and low-level switch on the standpipe. Thus, overall operation of the wells and the booster is controlled by system demand as reflected by the level in the standpipe, while operation of the well pumps and the booster as individual units is controlled by float switches reflecting the amount of water in the collection basin.

Operation of the booster pump had been extremely erratic, varying from a start and stop each eight minutes to once every three hours, depending upon the system demand. Installation of the modulating float valve has extended the length of time between shutdowns to several hours, and intermittent starting and stopping has been eliminated. The only time the pump shuts down now is when the motor is de-energized through the opening of the high-level switch on the standpipe, when it is filled.

The modulating valve was installed on the discharge side of the booster pump, connected through ½-in. piping to a remote-operated, reverse-acting pilot valve actuated by an ordinary float ball installed in the collection basin. As the level in the basin lowers, the float drops, causing the pilot valve to open. This in turn allows the modulating valve to begin closing, throttling the output of the pump. As the level in the basin rises, due to the throttling action of the main valve, the pilot valve starts closing, permitting the main valve to open. In effect, there is a constant pulsation of the main valve, which results in maintaining a fairly constant level in the collection basin. When the level remains constant, the valve remains in a fixed position, allowing the pump to discharge at a uniform rate.

The two types of valve have been very satisfactory and have served to decrease the maintenance expenditures of the California Water Service Co. considerably, prolonging the usefulness of transmission mains and pumping equipment.

Plastics

Improvements in the field of protective coatings offer many possibilities for improvements in water works practice. For example, there are being developed many interesting new synthetic thermosetting and thermoplastic materials which appear to have very good bond to metal, good resistance to abrasion and excellent resistance to conditions of exposure common in water works operations. These products have not been thoroughly tested in practice, but they are promising and may yet eliminate many vexing corrosion problems with steel water lines, valves, fire hydrants, pumps, pressure regulators and storage tanks.

Present procedure involves cleaning the article to be protected thoroughly,

and then applying the plastic resin coating by brushing, dipping or spraying. After evaporation of the solvents used as a vehicle, the coating must be cured by baking at a time and temperature dependent upon the properties of the resin used.

The finished coating has a smooth, hard surface, sufficiently flexible to dent rather than shatter and sufficiently resilient to resist considerable abrasion. Proper curing is required to obtain these properties and special equipment must be designed to make this process practicable. Portable heating devices making use of infra-red reflecting lamps seem promising, both for plant and field application.

Silicones

Chemical research has developed a family of materials called silicones. These include fluids for high- and low-temperature use having little viscosity change, chemically resistant greases, insulating resins, lubricants and rubber-like substances, in which silicon is used to replace the carbon of the usual compounds. The resulting products have many properties that are superior for special purposes to those of the standard organic products. For example, it is possible to build electric motors insulated with silicone products that will operate safely at temperatures as high as 350° F., thus permitting lighter weight equipment. Silicone greases which will dependably lubricate motors operating at such temperatures are also serviceable at − 4° F. Silicone varnishes and lacquers will not char at 350° F. and are serviceable at even higher temperatures. Silicone fluids are available for use in hydraulic systems for temperature conditions approaching − 70° F.

Pressure Welding

A new method of field-welding steel pipelines, called "Pressure Welding," has been employed for some time in the oil industry, notably in the "Big Inch" and "Little Inch" pipelines. Although at the present time this method is not applicable for steel water lines, the authors feel that the procedure should be called to the attention of water works men.

In pressure welding, no welding rod is required. It differs fundamentally from fusion welding in that the parts to be joined are not heated to fusion temperature but are forced together under a controlled application of heat and pressure. Assembling and welding of steel pipe by this method is done aboveground. The ends of the pipe are properly prepared and ground square for a butt weld. Pressure welding clamps are placed around the two ends of pipe to be joined and a circular oxyacetylene welding head is lighted. When the correct temperature is attained, the ends of the pipe are brought together by means of the pressure welding clamps, and a forging and welding action is completed within a few seconds. Tensile, free bend and nick break tests indicate that the resulting weld is excellent.

Supervisory Control

Supervisory control of pumping plants and valves will be utilized to a greater extent in the water works field. As the term is generally applied, supervisory control includes both telemetering (which is the electrical means for measuring the state of a substance or the status of mechanical equipment, transmitting the result to a distant station and there indicating or recording it) and remote control to alter the situation if necessary.

Though supervisory control is not new, having been used successfully in the power supply industry for approximately 25 years for central station control, it has only recently found widespread favor in other industries. Two recent examples of the application of supervisory control are its use in the control of all processes in a large steel mill and in the control of pumping plants along a 1,261-mile pipeline delivering different petroleum products to as many as seventeen points over single, paralleled and branched pipes of various sizes.

Considerations favoring supervisory control are the delegation of responsibility for proper operations to a single individual, thus eliminating errors due to confusion or misunderstanding; the increase in speed of operation, particularly in the closing of valves when breaks occur in major trunk lines; and, if actuated by recently developed ultra-high frequency equipment, the increased reliability when standard transportation and communication facilities are disrupted by earthquake, flood, tornado or other major disaster.

Assuming supervisory control to be advisable in some systems, it is well to consider automatic control of pumping plants and valves in the system, either as an alternative or a supplement to a supervisory system. The usual features incorporated in the Los Angeles Department of Water and Power's 33 fully automatic pumping plants include: automatic priming when suction lift occurs; blocking of controls if there is no suction on a positive suction line; automatic starting, in most instances by pressure switches located in the plant; automatic selection of units to rotate service of the units in any one system; automatic lockout of a unit if there is no flow after a predetermined time, and many other features. In several instances automatic controls have been installed on valves to regulate the amount of flow into branch lines, depending upon water level in a reservoir or pressure conditions in the trunk line.

Usually it is advisable to consider a combination of supervisory and automatic controls, determining to what extent such controls should be carried in an extensive water system. Telemeter recording of water levels in major reservoirs and water pressure at strategic locations in major trunk lines would be highly advantageous in any system of operation, and the means used to transmit this signal can also be designed to operate electrically driven gates or valves. Perhaps major pumping plants should be controlled from the dispatching office; it would then be advisable to incorporate all of the automatic features previously mentioned, with the addition of hot-bearing lockout. The automatic controls could be arranged to cut in upon failure of the supervisory system or at the will of the operator.

Various electromechanical means for both telemetering and control have been on the market for many years, and a new type of electronic control is now available. Various means of signal communication have been employed, including direct wire, carrier current, leased telephone company channels and radio. No doubt some form of radar equipment will be available in a short time. To operate such equipment at locations where no power is available, it would be necessary to install some form of power generation; perhaps the most satisfactory would be a battery supply, kept charged by an automatic engine generator.

Laboratory Devices and Research

New materials and equipment for the research laboratory include the new electronic devices now becoming available, which will provide more accurate determinations of stresses, defects, pressure surges and other conditions about which too little is now known.

One device used for the measurement of strains in structures depends upon the variation in electrical resistance of certain very small-diameter alloy wires according to the amount that they are stretched or compressed. These fine wires are cemented to the structure to be stressed and connections are made to one side of a balanced Wheatstone bridge. As the structure is stressed and a strain is produced, it is necessary to change the resistance on the other side of the Wheatstone bridge to restore a balanced condition. It is possible to calibrate the change in resistance required for balance in terms of strain for any given gage. Studies indicate that this gage, when properly operated, is accurate to 0.00001 in., or approximately 300 psi. for steel members. This device can be used with a cathode-ray oscillograph to determine rapidly changing strains such as might result from water hammer, pressure-regulator operation or other conditions which cannot be satisfactorily determined with conventional strain gages due to the inertia of the moving parts.

A device is also available for indicating almost instantaneously the changes in pressure in a water distribution system which may result from improper operation of pumps, valves, regulators or other mechanical equipment. The gage depends for its operation on the change in electrical resistance of certain salt crystals under varying pressures. This change in resistance causes a change in the voltage drop impressed across an oscillograph and results in a visual picture of the pressure wave on the oscillograph screen. Such a device has negligible mechanical inertia and can indicate pressure changes occurring at frequencies as high as 100 kc.

A recently developed method for rapidly detecting flaws in ferrous metals may be applied to the detection of cracks and flaws in cast-iron pipes and other water works materials. Such flaws in pipes are particularly difficult to detect because of the cement linings and bituminous coatings which prevent visual location of small defects. The device mentioned makes use of an oscillograph to indicate any variation in magnetic flux caused by change in the character of material being inspected. A crack or flaw in the cast iron changes its magnetic properties enough to be indicated on the oscillograph screen. Due to the press of war work, sufficient research has not been conducted to indicate how satisfactory this device will be in the inspection of water works materials, but plans are now being made to study this problem.

Problems for the Water Works Manufacturer

By Willard F. Rockwell

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Presented on May 10, 1946, at the Annual Conference, St. Louis, Mo.

INFLATION is the most serious problem the manufacturer must meet today, just as it is the most serious problem facing water works engineers, operators and their customers—that is, everybody. Inflation represents a rise in the price level, which usually occurs when people decide that commodities or real estate or corporation stocks are likely to rise in value. On the other hand, deflation usually occurs when people think that the prices of commodities, real estate and other things of value are about to decline. If a speculator buys something in a rising market, he can sell it later and have more dollars. If he sells something in a declining market, his dollars will buy more of the same item after the price has dropped.

The type of inflation which Germany had after the first World War and which is now going on in Austria is based on the fear that money will soon become of no value whatever. People, therefore, try to exchange it for anything of value before the money value shrinks to zero. Our country is in no danger of such extreme inflation.

Money is a medium of exchange; and money transactions are carried on in most civilized countries by the use of printed pieces of paper which are essentially promises to pay in some substantial form of wealth, such as gold or silver. If the government becomes unstable through rising debt (usually caused by war), the value of its money can shrink very rapidly until eventually it may have no purchasing power whatever—the final stage of inflation. Just as soon as the government starts to print more money, or increases its debt without having sufficient gold, silver or other assets, the value of money declines. Even the money issued by a stable government is of no value when it will not buy water, food or clothing. A castaway adrift in a small boat in mid-ocean might die of thirst, starvation or exposure, no matter how many million dollar bills he had with him.

Wages and Costs

If the cost of anything bought in normal times is analyzed, it will be found that at least 85 per cent of the amount represents money which has been paid to labor either on the farms, in the mines, the forests or the factories. In normal times, money and labor are interchangeable on a fixed basis. When, in times of deflation, labor cannot find work, the prices of all commodities go down, because labor is cheaper. In boom times, labor becomes scarce, wages rise, the prices of all commodities rise—and the result is inflation. The present government policy of enforced wage increases must soon come to an end. Bernard Baruch

told Congress recently that it is just "bunk" to say that wages can be increased without increasing the costs and selling prices of all commodities, and this principle has been demonstrated many times in the recorded history of the past 2,000 years. As Plutarch said, "The man who first ruined the Roman people was he who first gave them treats and gratuities."

There can be inflation and deflation at the same time in different kinds of labor and products. Inflation is brought about by scarcity of labor or lack of faith in the value of money, which promotes speculation in commodities or stocks. Beneficial deflation is usually brought about by labor-saving inventions or methods which cut labor costs for certain commodities and permit lowered prices. Dangerous deflation is brought about by surplus of labor, or by a surplus of commodities, or—an occasional aftermath of excessive speculation—by a shortage of good sound money to carry on business transactions.

We have had increasing inflation in this country for 50 years, despite occasional periods of drastic deflation. Examples of inflation may be found in any work which has not benefited from mechanical or labor-saving devices. Forty years ago, it cost 40¢ for a haircut and shave, or 20 per cent of the day's wages of $2.00 for a semi-skilled laborer. Today, in many of our big cities, it costs $1.60 for a haircut and shave, which is 20 per cent of the $8.00 a day which the semi-skilled laborer now receives. Therefore, although the semi-skilled mechanic receives four times as much in wages, he pays four times as much for the services of a barber; so, relatively, he has gained nothing and lost nothing by inflation in such transactions. Every increase in wages which is not based on increased production is definitely inflationary.

On the other hand, in 1906 it cost $5.00 to buy a Gillette razor, which could be bought for less than 50¢ in 1941, or a reduction of more than 90 per cent as a result of mass production, labor-saving methods and competition in the face of overall inflation.

Inflationary Practices

The trade of bricklaying clearly demonstrates the decline in the value of money and the inflationary rise, accelerated by artificially restricted output, in labor costs. Forty years ago, a bricklayer received $2.00 a day and averaged 2,000 bricks per day, with some workmen laying as many as 2,700 bricks per day, so that the average cost was $1.00 per 1,000. Today, bricklayers in many communities are receiving $15.00 per day and average less than 500 bricks per day, so that the cost has risen from $1.00 per 1,000 to about $30.00 per 1,000, an increase of 3,000 per cent. The semi-skilled worker, therefore, whose wages have increased from $2.00 per day to $8.00 per day, receives 4 times as much in wages, but he now has to pay 7½ times as much if he wants a bricklayer to build a brick wall.

The practice of artificially restricting the number of workmen is an inflationary device that has been followed in many other trades. In some communities, no one can become a licensed plumber without passing an examination prepared by the Board of Licensed Plumbers, which quite naturally is not eager to see the plumbing trade have a deflationary excess of available labor and shortage of work. No regulations prevent the inflation that results from this artificial restric-

tion of labor supply, although all agree that it is necessary to the public welfare to prevent corporations from artificially restricting production to obtain higher prices.

Inflation and Speculation

The greatest beneficiary of inflation is the owner of excess assets which rise in value and for which the owner is partly indebted in dollars or other money. For example: if a man buy a $1,000 machine, give his note for the cost, and sell the machine a year or so later for $2,000, he can pay off his note and make $1,000 profit. Of course, if he has to buy another machine, he has to pay $2,000 for it, so he has gained nothing.

Interest rates usually rise during inflation, because, if people are able to borrow and speculate successfully on the rising market, they can pay their debts very rapidly. On the other hand, the real victims of inflation are the people whose money is invested in securities or loans which have a fixed money face value and yield a fixed income; for, as commodities are increasing in value, there is no compensating increase in the value of the fixed debt.

Everyone who has insurance or who benefits from any kind of endowment or charity loses by inflation because loans and bonds do not rise in value and because interest rates on the normal prime investments do not increase; thus the buying power of the fixed income is greatly decreased.

A prime example of the loss of income and the shrinkage in buying power of charitable and endowed institutions is offered by the Carnegie Corp., which in 1943 received an average income of 2.7 per cent on investments that in 1923 had yielded 5.2 per cent. In the same period that the institution's income dropped almost 50 per cent, the prices of services and materials increased from 40 to 100 per cent, so that the present income buys only a fourth as much as it once did.

The greatest inflation today comes from the increase in wages, combined with the reduction in output per man, and the restricted output per machine. The Ford Motor Co. has accurate records to show that production per man decreased over 30 per cent during the war, even though wages increased 40 per cent. If the prewar dollar brings only 70¢ worth of prewar output, for which the worker receives $1.40, the buyer pays $1.40 for what cost 70¢ a few years ago. This is an increase in cost of 100 per cent, or 100 per cent inflation in a 5-year period.

Production-Consumption Balance

Walter Reuther, now Pres. of the United Automobile Workers, says, "Arbitrary raises in wages unaccompanied by increased productivity are not good." He knows that, at best, they can only increase the income of any class of workers if such arbitrary raises are denied other classes.

Every man who produces more than he and his dependents consume is adding to the national wealth. People who do not produce more than they consume must be supported by the labor of others. As a result of this war, many disabled veterans and the widows and orphans left by servicemen are entitled to support from public funds; but it must be recognized that only producers, whether they be laborers or corporations, can and will provide the tax funds for such government expenditures.

It is our industrial production which enables the farmer to produce more, the workman to produce more and our

shipyards, airplane and munitions factories to produce the material for our armed forces and our allies, without which we could not have won the war so quickly and decisively. There is no more patriotic action possible, in peace or in war, than to produce more than we consume. Production pays off our debts and raises the standard of living, so that the luxuries of today will be available to every one of us and to our children.

Beneficial Deflation

Production, furthermore, counteracts inflation and brings costs down. The use of mass production methods and labor-saving equipment, as well as competition between manufacturers, usually results in deflation. In 1925 it cost $31.50 per horsepower to buy an automobile, or $3,150 for a 100-hp. car. In 1940 it cost only $9.10 per hp., or $910 for a 100-hp. automobile. During that 15-year period, the daily wages of automobile workers increased more than 40 per cent because of the competition by manufacturers for that type of labor. The rise in the value of labor and the decline in the cost of the automobile enabled millions of workers to buy cheaper and better transportation. As a result of the increased demand, the cost of the automobile declined more than 60 per cent while wages of automotive workers were rising more than 40 per cent.

Washing machines cost $85 more in 1923 than they cost in 1940; and many other household labor-saving appliances have similarly improved in quality while decreasing in price, enabling the workman's wife to join in the better and higher standard of living, with more time for other work or pleasure.

Three hundred years ago, when nearly all farm work was done with only the simplest of tools, it required 9 out of 10 workmen in this country to raise the food and fibers necessary for existence. Today, less than 20 per cent of our workers are required for such work. A bushel of wheat, which then took 173 minutes to produce, today requires only 3.3 minutes, using tractors and power-driven plows, reapers and binders. Machinery has freed the workers and greatly improved their standard of living.

Three hundred years ago, there were billions of dollars of undeveloped natural resources in this country, most of which were unknown and of little value until workmen were released from the necessity of spending 90 per cent of their working time producing the bare essentials in food, clothing and shelter. Every labor-saving invention, every method devised to increase production has lowered costs and prices, making more labor available to develop other resources and more labor-saving devices. And in this way, the production-consumption balance, unless interfered with, reduces costs and raises living standards.

The Government in Economics

As a manufacturer of water meters, the author should like to point out that meter costs are certain to be much higher in the near future. Meter manufacturers have been buying copper under a government subsidy, at 12¢ a pound, but the price will certainly go to 14¢ or 16¢ in a free market. They are paying 52½¢ a pound for tin, although the ore alone costs the government between 60¢ and 70¢ a pound. The government can continue in business and take such losses, but manufacturers cannot. Some time in the future, tin may cost as much as $1.50 a pound. Costs are sure to be much higher and

prices must also be higher to maintain even the present low level of profits.

In early 1945 government economists convinced the politicians in power that there would be enormous unemployment and, therefore, deflation immediately after VE Day, their estimates ranging from 8,000,000 to 35,000,000 unemployed. In February 1946 Mr. Bowles admitted to a Congressional committee that every preliminary estimate on the effects of terminating war production was wrong, but he wanted to retain power to carry out his newest theories. At the same time, Secretary of Agriculture Anderson said nearly all grain shortages were caused by government-established price patterns.

The Secretary of Commerce issued a report which claimed that wages in the automotive industry could be increased 25 per cent or more without decreasing the producers' profits, because the great increase in demand would lower material and overhead costs as a result of the greater mass production savings. Many months after this report had brought on the worst series of strikes in our history, it was repudiated; but the damage had been done and the first-quarter financial reports of industry will show some startling losses.

Refusal to raise OPA ceilings did not keep costs down. One foundry source of supply which had an RFC loan for many years was permitted to increase prices over 195 per cent, whereas other foundries were only granted a 20 per cent increase, a discrepancy which typifies the favoritism and folly of government pricing. Henry Ford II pointed out that a manufacturer who sold him parts at a prewar price of 50¢ was unable to obtain a new price of 60¢, forcing the Ford Co. to go to another manufacturer who had no ceilings and charged 80¢. One of the best foundries the author's company dealt with was willing to continue production if the OPA would grant a 10 per cent increase, but when this relief was refused, the firm had to go to another foundry and pay 30 per cent more. No businessman can understand the reasoning which prevailed in such weird decisions.

As a result of OPA ceilings and rising labor costs, some very startling financial reports have come to light. For example, a large automotive manufacturing company, which was shut down completely by strikes in the third quarter of 1945, lost $1,000,000, but, in the fourth quarter, with factories producing at a rising rate, the loss increased to $1,300,000. The General Electric Co. lost $13,000,000 in the first quarter of 1946, part of which may be recovered from the government under the carry-back provisions of the tax laws. General Motors Corp. lost $88,000,000 in operations in the same period, in contrast to the first quarter of 1945, when they paid millions of dollars in excess profit taxes to the government.

As many observers have pointed out, the government policy on VE Day was to fight inflation by holding down prices, and to avoid deflation by increasing wages. The federal government, as the principal beneficiary of the excess profits tax and the principal loser under the carry-back provision of the tax law, has adopted a policy which is extremely inflationary. It is safe to forecast that all manufactured commodities and construction costs will increase at least 50 per cent over prewar prices, unless new labor-saving machinery, technological improvements and mass production methods are introduced.

Conclusion

Every war since 1860 has brought on inflation through increased debt, increased taxes, increased government control and expenses. The deflationary forces which have prevented this inflation from lowering our standard of living have come from lower-cost transportation, the use of electrical energy, mass production methods and chemical developments.

The problem of the manufacturers in the water works industry is to battle against inflation by the use of all the labor-saving and waste-eliminating methods and machinery which are available. It is absolutely essential that they do not buy anything which is not necessary to maintain proper standards of health and safety unless it will reduce costs. This program must be followed until the tide of inflation has been turned and normal production can again take care of normal demands. Whether this will require two years or five years cannot be predicted, because it depends on the co-operation of our people, of our corporations and of our governmental agencies.

If the good common sense of our people is applied to the battle against inflation, we may look forward to the time when the ravages of war are offset, if not obliterated, and we shall once more be able to pursue the ways of peace and prosperity.

Failures of Domestic Hot Water Storage Tanks

By Charles P. Hoover

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Presented on May 7, 1946, at the Annual Conference, St. Louis, Mo.

EVERY week, according to the Dallas Plumbing Company of Dallas, Tex., more than 12,000 domestic hot water tanks are replaced because they have rusted through. "In no place where metal is employed for domestic use is its wastage so large and extravagant as that caused by the failure of hot water storage heaters" (1). Plumbers called in to repair or replace tanks that have failed in a short time sometimes attempt to explain the failure by saying it is due to "the chemicals in the water." This bit of information often disturbs the consumer, and he usually concludes that water that will eat out a galvanized-iron tank will most certainly ruin his stomach.

If the water supply is not chemically treated, or at the most is only chlorinated, the plumber sometimes points to a nearby trolley line or transformer, which, he says, "leaks electricity into the pipes and destroys the water tank."

Tank manufacturers also have their alibis. They say the failure cannot be the fault of their tank because "we have thousands in other cities where we never have any complaints, so it must be the water or some other unusual condition for which we are not responsible." It is true enough that cities furnishing water directly from wells usually have a water that is free of dissolved oxygen and high in calcium bicarbonate alkalinity. Such waters are not corrosive, but they do cause excessive scaling in hot water heater coils.

The use of water high in carbonate hardness, however, is not the solution to hot water tank failures. People generally are no longer satisfied with hard water supplies; this is evidenced by the large number of softening plants that have been built in recent years. According to H. M. Olson (2), there are now 665 municipal water softening plants in the United States.

Corrosion Control Experiments

In April 1935, experimental corrosion control work on hot water tanks was started at the Columbus, Ohio, Water Softening and Filtration Plant. The work included studies of:

1. The corrosive action of various types of water on galvanized tanks.
2. Advantages to be gained by adding sodium hexametaphosphate to high pH water.
3. The construction of a cold water de-aerator and the operation of tanks with de-aerated water.
4. Methods for lining tanks with special cement plastics (3) and the operation of cement or so-called stone-lined tanks.
5. Methods for lining tanks with plastics and the operation of plastic-lined tanks.

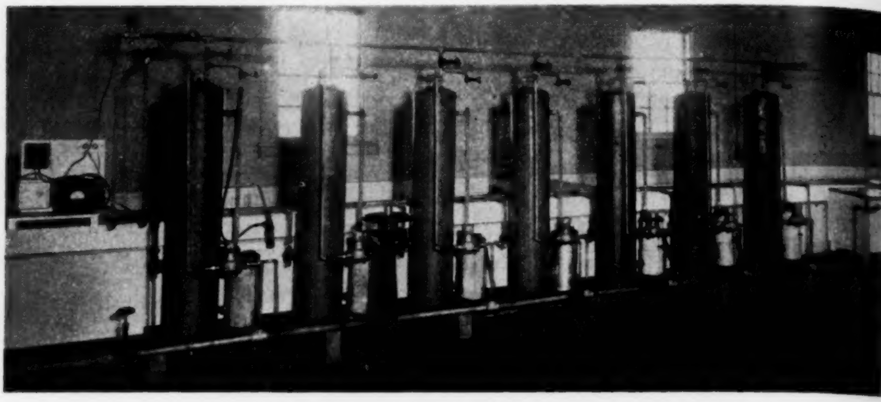

FIG. 1. Hot Water Tanks Being Tested

6. Construction of a transite pipe hot water storage tank and its operation.

7. Cathodic protection of both galvanized and ungalvanized tanks.

The tanks used were standard 30-gal. capacity types, such as are used in the average home. They were operated so as to simulate, as nearly as possible, actual domestic operation, and the temperature was held at 150°F. Weekly composites of water entering and leaving each tank were collected and analyzed for alkalinity (methyl orange and phenolphthalein) and iron; special samples were also collected and analyzed for dissolved oxygen. The period of operation of the tanks was from one to two years. At the end of the operation period, the tanks were cut open vertically and examined. In all, 42 tanks were operated and cut open for inspection, and at present there are 7 tanks still in service (Fig. 1). Representative sections were cut from some of the tanks and microphotographed; from the photographs, the depth of the pits was measured.

Results of Experiments

It is impossible to include a detailed discussion of the experiments made and the results obtained during the past 11 years. An outline of the work may be found in the annual reports of the Division of Water, Columbus, Ohio, during the years 1935 through 1945 (4); some of the earlier results were published elsewhere (5, 6).

Some very general conclusions drawn from the results of the experiments are:

1. The inherent weakness of galvanized tanks is that they will not give satisfactory service unless the zinc coating holds out long enough for the water passing through to deposit an incrusting scale of calcium carbonate, or a protective corrosion product. It is, therefore, the scale so formed, which resurfaces the zinc, and not the zinc itself, that affords protection.

2. Cement, or so-called stone-lined tanks give excellent results.

3. Resinous linings are still in the experimental stage. They are not expensive to build, are light, and, if the lining can be made to stick, they should be very satisfactory. Those that were lined for the experiments had a tendency to peel.

4. Cathodic protection proved effective. The tanks soon became coated with a hard flint-like film that could only be removed for analysis by the use of a cold chisel and hammer. This

might prove to be a good method for coating tanks. At present the transformer and rectifying equipment is too expensive to make it competitive with higher priced tanks made of stainless steel, monel metal or copper.

A self-activated form of cathodic protection that eliminates the electrical apparatus, however, seems to have been developed by Leonard V. Sutton, who was granted a Canadian patent on May 4, 1943, entitled "Method of Protecting Water Heating Equipment From Corrosion." According to the claims of this patent, cathodic protection may be obtained simply by hanging a strip of metal, higher in the electromotive series than zinc or iron, in the tank.

Experiments are being planned at the author's plant to place a thick rod of magnesium in both a steel and a galvanized tank. Whether these rods, without connection to any outside source of electricity, will develop enough current flow to the tank walls to afford protection will be determined.

5. The results of the experiments indicate that the addition of polyphosphates (up to 1.5 ppm.) to high pH water, does not appreciably help or retard the formation of a protective calcium carbonate scale in hot water tanks.

Personal observations at a number of water softening plants, as well as the results of the experiments, indicate that galvanizing does not protect steel tanks when the alkalinity of the water is low (20 to 30 ppm.). This applies to natural waters as well as to lime-softened waters. It applies whether the saturation index is negative, neutral, or even slightly positive. Water with a negative index dissolves the zinc and carries it out of the tank as zinc bicarbonate. Water with a neutral or slightly positive index precipitates it as zinc carbonate, which is neither dense nor adherent and therefore provides no protection to the tank.

It should be remembered that low alkalinity water must contain normal carbonates in order to be in chemical balance to calcium carbonate. When such water is heated, enough normal carbonates must be present to produce a high positive index if galvanized tanks are to be protected. At Columbus the index is carried at + 0.8, with a pH value of 10.3. Sodium hexametaphosphate is added (0.35 ppm.) to prevent too much deposit in cold water lines. The coating produced by this super-saturation protects the tank, provided the water is not heated beyond 150°F. Since the adoption of this procedure about 8 years ago, very few tank failure complaints have been received.

It is regrettable, however, that these high pH values (10.3) must be carried, as they are not necessary except for the protection of the tanks. The filtering of such water incrusts the filter sand to the point where it must be replaced about every 10 or 12 years. Magnesium compounds, if left in such high pH water—and it is difficult to remove them—slowly precipitate in heater coils and hot water pipes. Unfortunately, good treatment practice must be compromised to protect galvanized tanks from corrosion.

Experiences encountered in army camps (*7*), where water is heated to 180°F., demonstrated very conclusively that overheating is probably the greatest contributing cause to premature failure of hot water tanks. Overheating causes corrosion with any kind of natural water, except perhaps when the water is free of oxygen. Merely advocating that temperatures be kept within reasonable bounds is not always effective. Many families have tanks

that are too small, and try to stretch the hot water supply by keeping the tank temperature too high. Table 1, recommended by the Pacific Coast Gas Association, gives the tank capacity suggested for homes of various sizes.

TABLE 1

Tank Capacities Recommended for Homes of Various Sizes

Number of Bathrooms	*Number of Bedrooms*	*Storage Capacity, gal.*
1	1 or 2	30
1	3 or 4	40
2	2 or 3	40
2	4 or 5	50
3	3	50
3 or 4	4 or 5	75

Galvanized hot water tanks are almost universally used in moderately priced homes because of their low cost and light weight. Despite their long history, however, most water plant operators would welcome a new protective coating that would not appreciably increase the weight and cost of the tank and would not be affected by bicarbonates, normal carbonates or temperatures up to about 180°F.

Contributing Causes of Failure

In spite of the plumber's opinion that chemicals cause premature tank failures, there are other reasons why tanks fail. Poor tank steel, poor galvanizing and the use of electrochemically dissimilar metals are undoubtedly contributing factors to premature failures of hot water tanks. Each is of sufficient importance to warrant a brief discussion.

Poor Tank Steel

According to Wallace G. Imhoff, of the American Hot Dip Galvanizers Association (8), "Defects in the base metal may be of two kinds—chemical and mechanical. There are certain chemical elements, such as phosphorus, sulfur and silicon, that indicate at once whether the steel melting conditions are right or wrong." Scale may be rolled deep down into the steel surface, or steel tanks may be rained on and rust in spots. Due to the heavy rust, it would be very difficult to pickle the tanks properly for galvanizing. Any rust imbedded under the zinc coating may crack or break it and leave the steel exposed to rapid corrosion. Such instances may be unusual, but their existence proves that the character of the water is not always the cause of tank failures.

Poor Galvanizing

Fabricating, pickling, fluxing, galvanizing and welding may be faulty and thus contribute to premature failures.

Tanks are pickled in sulfuric acid (6 to 10 per cent). The action of the acid upon the steel forms ferrous sulfate. This salt is extremely harmful to the flux solution and to the galvanizing bath. If it enters the bath in large quantities, it not only affects the zinc coating, but forms "galvanizer's dross." The tanks, therefore, must be thoroughly washed after pickling. This precaution is not always taken, for the author has removed a double handful of flux deposit from a new galvanized tank. Zinc ammonium chloride, rather than muriatic acid, is recommended as a flux by the American Zinc Institute, as it has the advantage of producing a better tank coating.

Tin or aluminum is used in the galvanizing bath to brighten the tank; and both, but especially tin, produce spangles which seem to make the tank more attractive to the purchaser. There is an

interesting report in the *Journal of American Zinc Institute* (9), on the premature failure of galvanized steel watering troughs. The report concludes that the presence of tin in the galvanizing bath is an important, if not the most important, factor in the rapid premature failure of stock water tanks.

Forty test tanks, or twenty sets of tanks, located in Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kansas, Nebraska and Colorado were studied. Each set of tanks consisted of one old and one new tank, both supplied from the same water source. The twenty old tanks, which had an average life of 24 years, were still in operation at the end of the test; whereas the new tanks had an average life of only 18 months. Spectrographical analyses showed the only difference in the galvanizing on the old tanks and the new tanks was that the new tanks contained about 1 per cent of tin, whereas the old tanks contained only a trace of tin.

The author is not prepared to say that the presence of tin in galvanized hot water tanks is responsible for their premature failure, for he has had only one opportunity to compare the performance of tanks with and without tin incorporated in the zinc. The tank with tin in the coating failed in one year; yet in the author's own home there is a tank that had been in service for 18 years. The tin content of the coating in the new tank was 1 per cent; in the old tank there was only a trace of tin. Frankly, the author is suspicious enough to pick a dull tank, if he had to buy a new one, rather than one that was highly spangled with tin.

Dissimilar Electro-Chemical Metals

Dr. E. P. Schoch, Professor of Chemistry at the University of Texas, testified before the City Council of Dallas, Tex., during their investigation of premature failures of hot water tanks, that, as an electrochemist, he is horrified at the design of the tanks. Copper and iron pipes, zinc, and a liquid solution between them, and the result is a battery cell.

The voltage difference between various cold water inlet pipes or tubes and the metal of the tank proper has been shown by N. C. Hammer in a report to the City Council of Dallas. The results show that there is a possibility that these inlet pipes, which are of dissimilar metals, will set up galvanic action.

The author knows that galvanizing is not always good for he has personally inspected new tanks and has found bare spots as large as a silver dollar. Although he does not wish to imply that tank failures are always due to poor material, poor processing or poor design, the author does want to contend that failures should not always be blamed on the water. Many tank failures can be eliminated by more careful manufacturing methods.

Tank Corrosion Prevention

The water consumer as well as the tank manufacturer may also do a great deal to prevent tank failures. The selection of a well-built tank of sufficient capacity would in itself be of considerable benefit. It would also reduce the need of heating the water above the critical temperature of 150°F., which would further contribute to the conservation of tanks.

The various treatment methods that may be adopted will not be discussed in detail; before mentioning them, the author wishes to point out that there is a difference between what *can* be done

and what *should* be done in water treatment processes. Tank corrosion can be minimized by:

1. De-aerating the water.
2. Hardening the water so that it will lay down a protective scale.
3. Adding sodium silicate to the water to form a protective scale.
4. Adding polyphosphates to the water.
5. Treating the water so that it is in chemical balance to calcium carbonate or slightly in excess. In other words, carrying a neutral or slightly positive Langelier Index.
6. Supersaturating the water with calcium carbonate to the point where it literally plasters the inside of the tank with calcium carbonate. In other words, carrying an excessively high positive Langelier Index. If this is done, polyphosphates in small quantities should be added to prevent too much deposit of calcium carbonate scale in cold water pipes.

De-aeration

Results of the experiments indicate that de-aeration of Columbus tap water completely eliminates tank corrosion. It would, however, be hard to follow such a practice. Much of the water used in cities is stored in large reservoirs and will reabsorb oxygen from the air during the storage period. Such water would also dissolve any rust in the distribution system. Until the mains are completely cleaned this treatment would plague the consumer with rusty or red water. Also, the expense of de-aeration is high. The installation cost is estimated by the Permutit Co. to be $10,000 for a 1-mgd. plant, and $200,000 for a 50-mgd. plant. The operating cost is estimated to be about $2.00 per mil.gal. to reduce oxygen to 1 ppm.

Increasing Carbonate Hardness

Hardening the water is, of course, undesirable, and some of the supplies on the eastern coast contain too small an amount of free carbon dioxide to be stabilized. To stabilize water of this kind requires both lime and carbon dioxide unless the treatment is carried to the point of causticity. Frank E. Hale, of the New York City Water Dept., has stated on numerous occasions that he is opposed to hardening the Catskill supply, one of the softest municipal water supplies in the country. He has always recommended that the customers use the best plumbing material available for this kind of water, and stresses particularly that it does not pay to buy cheap material for extensive use.

Use of Sodium Silicate

It seems unreasonable to expect a water department to treat its entire supply with sodium silicate simply to prevent corrosion in hot water tanks. This chemical forms scale in the mains and extra silicate in the water may be objectionable to operators of steam boilers. Unless needed to prevent corrosion in the distribution system, it should not be used.

Addition of Polyphosphates

The experiments indicate that the addition of polyphosphates, up to 1.5 ppm., to high pH water, that is, water that is stabilized or highly supersaturated with calcium carbonate, does not appreciably help or retard the formation of a protective calcium carbonate scale in hot water tanks.

Chemical Balance to Calcium Carbonate

The experiments also show that low alkalinity water (25 to 30 ppm.) which

is in chemical balance to calcium carbonate is very destructive in hot water tanks. The walls of the tanks become partly covered with calcium carbonate, but numerous corrosion spots develop and corrosion concentrates at these points. The tank is apt to develop leaks more quickly than when the corrosion is more uniform throughout the entire area of the tank. Figure 6 of a previous paper by the author (10) shows a tank that was operated for one year with water of this composition passing through it.

Conclusions

Galvanized tanks have a long history behind them; they are cheap, easily installed and well established in the trades. They will undoubtedly be used for some time to come, but probably will be replaced, eventually, by something better. Until then, the water treatment plants, the manufacturers and the home owners should co-operate to the utmost in eliminating, or reducing, the excessive waste now caused by the failure of hot water tanks.

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Corrosion of Galvanized Hot Water Storage Tanks

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Presented on May 7, 1946, at the Annual Conference, St. Louis, Mo.

IN the following discussion of galvanized hot water storage tanks, it is assumed that all corrosion is electrochemical under the conditions existing in a hot water system. Electrolytic corrosion in water is the result of two simultaneous reactions: the solution of the metal in the form of metal ions at the anode, and the liberation of an equivalent amount of hydrogen by reduction of hydrogen ions at the cathode. These reactions involve the flow of electrons from the anode to the cathode through the metal. The solution of the metal at the anode results in a film of solution which is relatively concentrated with respect to the metal ion; and increasing ionic concentration of the film causes the anode to become more electropositive, that is, its tendency to go into solution becomes less. At the cathode, liberated hydrogen acts as a hydrogen electrode, and the hydrogen ion concentration in the cathode film is reduced, due to the formation of atomic hydrogen. This change in hydrogen ion concentration results in a reduction of the cathode potential.

These two potential changes are known as anode polarization and cathode polarization, respectively. The corrosion rate is proportional to the current flow and is decreased when polarization reduces the potential difference between the anode and the cathode.

The limiting concentration of the metal ion is dependent upon the solubility product of the hydroxide, carbonate, or basic carbonate, or other insoluble corrosion products. The precipitation of insoluble films of these corrosion products will reduce the corrosion rate by mechanically restricting the diffusion of the products of corrosion from the surface and preventing the access of fresh corrodent to the surface of the metal.

When galvanized steel corrodes in water containing bicarbonates, zinc carbonate is produced at the anode and calcium carbonate is electrochemically precipitated at the cathode. Corrosion ceases when a complete film is obtained. In hard water, this occurs in a comparatively short time and results in good service life of the hot water storage tank.

The prime factor in controlling the corrosion rate in water is the depolarization of the cathode film of hydrogen. In acid solutions, this is accomplished by mechanical removal of the hydrogen as gas bubbles. In potable water containing dissolved oxygen, the hydrogen film is depolarized by oxidation. If air-free water could be obtained, then there would be no corrosion problem. A test reported by Hoover (1), using de-aerated water in a range boiler, showed no corrosion, with iron-free water during the one-year test.

In order to simplify the various factors involved in the corrosion of galvanized hot water storage tanks, they may be classified as either internal or external factors. The internal factors are those inherent in the materials, and can be controlled by the manufacturer. The external factors are those which the manufacturer cannot control. Internal factors include the steel, zinc, proper cleaning, fluxing and galvanizing practice. The galvanic protection of the steel by the zinc coating is an inherent property of the materials and may be considered an internal factor.

Internal Factors

The steel used for the construction of the tanks is generally a low carbon, basic open-hearth, rimmed, hot-rolled sheet. The analysis conforms to Society of Automotive Engineers' specifications 1010 or American Iron and Steel Institute's C 1010 specifications. This type of steel is used because it presents the most desirable surface for galvanizing. It can readily be formed into tank heads and bottoms and can be welded by automatic machines.

In regard to the effect of the analysis of open-hearth steel on corrosion, Speller (2) states: "This metal is used for galvanizing, enameling, electrical apparatus, roofing material, wire and other purposes where a very ductile form of highly pure iron is desired. At one time, some investigators felt that iron of such high degree of purity was the main solution of the corrosion problem. These expectations have not been altogether realized, as tests and experience seem to indicate that in most cases extreme purity is not so important as other considerations."

The most common tramp alloy found in steel today is copper. In regard to its effect on under-water corrosion Speller (2) states: "As a rule, the addition of copper to steel appears to have no decided influence one way or the other when the metal is exposed under water or in the soil."

The zinc commonly used for hot dipping conforms to the A.S.T.M. Specifications (3) for Prime Western grade. The effect of various alloying metals on the corrosion rate of zinc in half-normal sulfuric acid has been shown to accelerate corrosion except in lead, aluminum and mercury (4). The effect of these alloying elements on the corrosion rate of zinc in potable water has not been determined. The data cannot be extrapolated from half-normal acid to hot water because depolarization in the acid is by hydrogen evolution, whereas in water the depolarization is primarily due to dissolved oxygen. McKay and Worthington (5) state: "In spite of this evidence of the positive effect of impurities, however, it was generally true that variations in the type and quantities of impurities as they exist in sheet zinc and zinc coatings carry no virtual demonstrated significance from the corrosion angles."

The conclusion that tin in the zinc coatings will cause rapid failure in hot water tanks is not warranted from observations of stock watering tanks. Corrosion data obtained under one set of conditions cannot be applied *per se* to corrosion occurring under entirely different conditions where other external factors control the corrosion rate.

Although considerable data have been obtained regarding the mechanical properties of zinc coatings alloyed with various metals, no data have been found concerning the effects of these alloys on the corrosion resistance to hot water. It may be found that some zinc alloy coating will offer greater service due to

the properties of the corrosion product film.

The third and very important factor which can be controlled by the manufacturer is the correct preparation of the steel and galvanizing pot operations. The sequence of operations includes: (1) the removal of grease and oil from the steel; (2) the pickling of the steel to remove all oxide or scale from the hot-rolling and welding operations; (3) a thorough rinsing to remove all acid and iron salts; (4) a dip in muriatic acid or preferably a zinc chloride ammonium chloride flux; (5) drying; (6) immersion in molten zinc maintained within proper temperature limits; (7) withdrawal from molten metal and cooling.

Control of the cleaning, pickling and flux bath is mandatory for good results. With the wartime development of electroplated coatings on steel, considerable research has been conducted on metal cleaning. It can be expected that this knowledge will be applied to the cleaning of metals prior to hot-dip coating.

Cleaning of the tank after tapping to remove the cuttings is necessary to prevent local oxygen concentration cells and premature pitting of the bottom of the tank.

External Factors

The "external factors" are those which influence the corrosion rate but which cannot be controlled by the tank manufacturer. These external factors include the variation in water supply, the rate of flow of water through the tank, the temperature of the heated water, rate of heating, pressure variations, and the introduction of galvanic couples by the use of brass or copper pipe or fittings. One of the factors controlling the corrosion rate is the depolarization of the cathode by dissolved oxygen. The amount of oxygen introduced into the hot water storage tank will be in proportion to the volume of water drawn from the tank and the quantity of dissolved oxygen present in the water.

The influence of temperature on the corrosion rate is exerted in five simultaneous ways. The first effect of temperature is to increase the rate of the chemical reactions which constitute corrosion. The second effect is the thermal softening of the water by decomposition of the bicarbonates to normal carbonates and the formation of scale on the heated surfaces. The softened water will be more aggressive than the original cold water when held in the storage tank.

A third effect of temperature is a reduction in the pH of the water. This may be further intensified by the release of free carbon dioxide from the decomposition of any bicarbonates present. The fourth effect of temperature is the dimensional change of the tank resulting from expansion of the metal when heated and from the increase in hydrostatic pressure resulting from the heating of the water. Pressure release valves will limit this latter effect. This breathing of the tank, if excessive, will loosen or crack the protective scale or film and expose bare metal to the action of the water. The fifth effect is the change in the nature of the corrosion product film. Cox (6) has investigated the attack on zinc by distilled water and concluded that the nature of this film, that is, whether the film is gelatinous and adherent or granular, flaky and non-adherent, controls the rate of attack.

The rate of heating and the method of application of heat to tank also influence corrosion. If large volumes of

hot water are required intermittently, the proper procedure would be to install a large storage tank to meet the peak demands, and to heat the water at a moderate rate during the off-peak time. The usual household practice, however, is to increase the temperature of the water by changing the setting of the thermostat. The resulting over-heated water is then mixed with cold water at the tap to give a large volume of water at the desired temperature. This practice produces red water and greatly reduces the service life of the tank.

A moderate rate of application of heat will reduce the amount of thermal softening and scale formation. Since the scale acts as an insulator on the heating surfaces, it will reduce the rate of heat transfer to the water. This is usually offset by an increase in the size of the flame to give a higher temperature difference. The cycle is repeated until an excessive amount of red water is obtained or until the heater fails to operate because the passages are closed by the scale.

The use of a horseshoe burner directly under a range boiler may reduce the life of a tank to as low as one or two years, because of local overheating. In a test at Columbus, Ohio, the galvanized range boiler heated by a burner below the tank failed in less than a year and a half, while other similar tanks which were heated by side-arm heaters showed no pitting after a two-year test (7).

The effect of pressure variations when caused by increase in temperature has been described. Pressure variations due to line conditions or water hammer will also cause a loosening or cracking of the protective film.

The use of copper or brass for cold water dip tubes, heater connections and thermostats is general practice. This introduces the galvanic couple where the copper or brass is protected at the expense of the steel or zinc; however, corrosion of the tank is not greatly increased because of the small area of brass or copper in comparison with the larger area of galvanized steel (8). Where copper or brass pipe or tubing is used with a galvanized steel tank, this area ratio of anode to cathode areas becomes unfavorable; however, the effective cathode area is still small and only a slight increase in corrosion is noted. Galvanic corrosion resulting from the use of copper pipe can be controlled by the use of insulating reducing bushings. It is recommended that all hot and cold water and gas lines be insulated from the tank with such bushings. One precaution must be observed if insulating bushings are used: the pipe must not be carrying an electric current. The flow of an electric current across an insulated pipe joint will result in intense local attack at the end of the pipe where the current leaves the metal and passes into the water.

The service life of galvanized hot water storage tanks has been the subject of many conflicting opinions. Wallace G. Imhoff, Technical Director of Research for the American Hot Dip Galvanizers Association, when asked why there is an increase in the failure of water tanks and heaters, said (1): "From my thorough study of this subject I am inclined to believe that the basic cause is the deterioration in the quality of the steel base."

The steel industry points out that the quality of the steel is better today than that obtainable 20 years ago because of improvements in equipment and instruments which afford more accurate controls of analysis, temperature

and rolling conditions.

On the other hand, a representative of the New Jersey Zinc Company Research Division stated (9): "It is our belief, at the present time, that the problem of corrosion of galvanized hot water containers is best solved by the control of the water itself."

The conflicting statements just presented were not intended to add to the confusion, but rather to show that different interests approach the problem in various ways.

Probably the most satisfactory explanation is offered by Evans (10) who describes the anodic protection of steel by the zinc coating and the cathodic film resulting from the deposition of calcium carbonate. Evans states: "The argument may explain why, in recent years, failures of galvanized hot water systems appear to have become more frequent. There is no reason to think that the zinc coats are sensibly thinner or that manufacturing skill has declined; but the water enters the tank or cylinder in a softer condition because the more efficient heating furnace, designed to meet the popular demand for hot baths on short notice, causes a considerable amount of softening in the boiler or in the pipes."

Summary

The internal factors which can be controlled by the manufacturer of galvanized hot water tanks are the steel and the zinc, and the preparation of the surface prior to galvanizing. The latter may be the most important internal factor with regard to service life. Changes in the analysis of the steel and zinc may give an increase in service life due to the properties of the corrosion product film. Tests have been conducted which indicate that increased resistance to pitting may be obtained by changing the coating (11).

The external factors were the quality of the water, rate of flow through the tank and, perhaps the most important factor of all, the temperature of the water and the rate of application of heat. Other external factors are pressure variations and galvanic couples formed by copper or brass pipe used with galvanized steel tanks. The use of nonferrous pipe or tubing has been a comparatively recent practice and may accelerate the apparent reduction in service life of galvanized tanks.

In line with the above discussion, the following recommendations are offered:

1. Select a tank of suitable capacity to meet maximum requirements of "usable" hot water.
2. Use heavy gage material to restrict mechanical "breathing" of the tank.
3. Insulate the tank so as to permit the lowest rate of heating.
4. Use a thermostat to limit the maximum water temperature.
5. Use a pressure relief valve to limit maximum water pressure.

By following these recommendations, one can obtain the maximum service life. In the final analysis, it is the maximum service life per dollar spent that is the solution to any corrosion problem.

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DISCUSSION—*Owen Rice*

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The use of a zinc coating for protecting iron is very old, and galvanizing has long been an established practice in the industry. The very term "galvanizing" is itself indicative of one of the principal reasons for this use of zinc—the galvanic action which causes the zinc, rather than the iron, to corrode. Thus the zinc coating continues to protect the iron even after it has been penetrated. In addition, of course, zinc is usually corroded by water less rapidly than iron, and its corrosion products, which are white, are less objectionable than is iron oxide.

Galvanizing affords excellent protection against atmospheric corrosion. It is this writer's opinion that galvanizing made its reputation in such service, for the long life of galvanized roofing and galvanized wire fencing is well known. The length of life of galvanized hot water tanks, however, is extremely variable—it varies from less than 1 year in many localities to 30 or 40 years in others. Where the life expectancy is short, what might be called the useful life of the tank is even shorter, because long before the tank wall is actually penetrated the zinc will have been removed, and discoloration of the water with iron rust will have rendered the water almost unusable for washing.

Unfortunately, the water that is least corrosive in galvanized hot water tanks is water that is hard and high in bicarbonate content, forming a protective scale of calcium carbonate over the entire tank wall. Of course, no one likes hard water, and almost everyone will prefer a naturally soft or an artifically softened supply even though corrosion of galvanized hot water tanks results. This is less extravagant than it may sound, even neglecting the effect of hard water on increased soap consumption, because it is probable that a water that will form enough scale to protect the inside of a hot water tank will also form so much scale that the heater coil will have to be replaced at frequent intervals, thus causing the householder almost as much trouble and expense as is involved in renewing a tank. Naturally, all of us want to have our cake and eat it too, and therein lies the problem. How to protect galvanized hot water tanks from the corrosive action of natural or artifically softened water supplies?

As soon as we attempt to treat the water in order to lengthen the life of the galvanizing, we encounter another dilemma. The galvanic action of a zinc coating requires the sacrifice of this metal as the fee for the protection of

any exposed iron. If we treat the water solely to protect the zinc, we tend to destroy the sacrificial action of this metal; we now rely upon the zinc solely as a coating, such as a paint film, to insulate the water from contact with the ferrous metal. Unfortunately, we cannot hope to do so perfect a job of protecting the zinc as to insure a very long life for a galvanized coating, which must be relatively thin (if thicker than 0.003 in., the zinc will flake and peel off the iron surface). Once penetration of the zinc coating occurs, conditions are very similar to those existent at a pin-hole in a painted steel surface; the oxygen content of the water is high, since little has been consumed by attack upon the protected galvanized surface, and conditions are ripe for extremely rapid attack upon the limited area of steel laid bare by the perforation in the galvanized coating. As a result, rapid penetration of the base metal of the tank occurs with the formation of a pin-hole leak; whereas, if the zinc had not been so well protected, the area of attack would have been widened and the failure delayed. And right here is where poor galvanizing enters the picture, for many cheap tanks have large spots bare of zinc when installed. In one examination of the stock in a warehouse of a leading wholesaler, it was found that 79 out of 80 tanks showed bare spots. For this reason, it is often possible for galvanized hot water tanks to fail more rapidly with water conditions which should give the maximum protection to zinc than with waters which are actually far more corrosive to the galvanized coating.

Thus, in practice the problem of protecting galvanized tanks resolves into the problem of protecting the base metal, steel.

High pH, which tends to produce a pitting attack upon steel, is apt to lead to an even more severe localized attack of galvanized tanks by lowering the protective galvanic effect of the zinc coating. Unfortunately, lowering the pH of an uninhibited water, which would probably create a red water problem, is not practical, even though it would make corrosion more uniform and prolong the actual life of the tank. The pitting action resulting from high pH forms the basis for this writer's recommendation that the best results for corrosion control with Calgon (sodium hexametaphosphate) can be obtained at neutrality or slightly below (pH 5 to 7); actually, approximately the same degree of corrosion inhibition can be attained with Calgon at high pH values, but what attack does occur is of the pitting type characteristic of this high pH range.

In a softening plant where, in effect, the water is already of high pH, it may prove satisfactory to keep the pH up as recommended by Hoover. The writer believes, however, that a minimum value of 10.4, considerably higher than is customary, is desirable, since the corrosion rate of both zinc and steel drops rather markedly as the pH increases above 10.4. This point is still to be decided but, at any rate, the writer believes that the pH range of 8.0–9.5, which generally includes the stability pH, is apt to be the most damaging of all, even though "red water" is decreased; for the pH in this range is neither high enough to give protection nor low enough to avoid localizing the attack. Moreover, there is usually not enough calcium carbonate to form an effective scale coating on the walls of the tank. Confirmation of this opinion is indicated by the results reported by C. F. Bonilla, Professor of Sanitary

Engineering at Johns Hopkins University (1).

A high pH has one important advantage that seems to have been overlooked. Much has been said of the deleterious galvanic effect of a copper drop tube in a hot water tank. To this the writer can only say that he has examined many tanks that have failed and has yet to see one where the pitting was pronounced near the copper-zinc-iron junction, where failure should occur if the copper pipe were a contributing cause.

On the other hand, no mention has been made of the action of minute amounts of dissolved copper. This action is very deleterious to zinc and so would cause a rapid failure of the galvanizing. Table 1 shows the influences of dissolved copper and Calgon upon zinc strips suspended in Pittsburgh tap water (pH 6.5) at room temperature for five days.

TABLE 1

Effect of Dissolved Copper on Zinc

Copper Content *ppm.*	Zinc Weight Loss *mg./sq.dec./day*		
	Calgon *ppm.*		
	0.0	5.0	10.0
0.01	32.3	12.2	8.7
0.2	105.0	21.5	10.0
0.5	116.0	16.9	71.1
1.0	119.0	71.1	18.5

The pronounced effect of only 0.2 ppm. of dissolved copper is clearly indicated. High pH, to the extent that it prevented solution of the copper, would thus be advantageous.

Another important effect of Calgon in protecting galvanized hot water tanks, is that it inhibits the attack upon the steel. Reducing the attack on the steel makes sacrificial corrosion of the zinc unnecessary. It thus inhibits the attack upon the zinc without losing the protection of galvanic action for any bare steel which may be exposed in the system. Table 2 shows the protection

TABLE 2

Effect of Calgon on Corrosive Galvanic Action

Calgon *ppm.*	Weight Loss *mg./sq.dec./day*	
	Steel	Zinc
	Plates Separated—No Contact	
0	1270.0	20.5
	Plates Coupled	
0	374.0	144.0
5	1.3	83.0
10	0.4	59.0
25	0.4	45.0

afforded by Calgon to coupled zinc and steel plates of equal areas when exposed to Pittsburgh tap water (pH 6.7) at 176°F.

The relatively high feed of 5 or 10 ppm. of Calgon which seems to be required to protect hot water tanks is made necessary by the more corrosive conditions under which basic zinc carbonate and iron oxide which adsorb Calgon from solution are generated more rapidly. Also, the lack of turbulence in the tank and the low volume of water used per day, in comparison with the area of metal exposed, tend to reduce the amount of Calgon actually reaching the surface of the metal where it can be adsorbed and exert its protective action.

To date no city has used a sufficient feed of Calgon to afford adequate protection to the hot water tanks of the consumers. Such quantities of a similar glassy phosphate, Micromet, have been supplied to several thousand hot water tanks, particularly in Little Rock,

Ark., and Dallas, Tex., since 1942. But just how long such treatment will prolong the life of a galvanized tank is still unknown, since at this writing no new tank treated with Micromet has yet failed, even though identical untreated tanks continue to fail at intervals of one to two years. From the laboratory data given above, at least a tenfold prolongation of the life of these hot water tanks might be expected from such treatment. The writer does not consider the cost of such treatment to be excessive.

Reference

1. Bonilla, C. F. Pipe Service Tests on Baltimore Water. Trans. Electrochem. Soc., **87** (1945).

Federal Specifications—Water Works Materials

The American Water Works Association has developed no specifications for centrifugally cast cast-iron pipe, calking lead, nor for sulfur compounds for jointing bell-and-spigot pipe. Inquiries concerning specifications for these materials are referred to the Supt. of Documents, Washington 25, D.C., through whom the following documents may be obtained:

WW-P-421	pipe; water, cast-iron (bell and spigot)
QQ-L-156	lead; calking
SS-C-608	compounds, jointing; sulfur (for bell-and-spigot cast-iron pipe)

These documents are priced at five cents per copy, postpaid. Postal money orders made out to the Supt. of Documents, Washington 25, D.C., should be enclosed with each order. Checks or postage stamps will not be accepted. Currency is sent at the risk of the sender.

German Methods of Heating Water for Domestic Use

By H. L. Anthony

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Presented on May 7, 1946, at the Annual Conference, St. Louis, Mo.

FOUR months after VE Day, the author had the opportunity of participating in a mission for the Federal Economic Administration in Germany which involved the investigation of certain German processes in the manufacture of pressure containers. It was at this time that general observations were made of German methods and apparatus by which water was heated for domestic use. These observations were made in billets which were provided either by the U.S. Army billeting officers or by Military Government billeting officers. Such billets included the ordinary residences, apartments, lodges, guest houses, air raid bunkers and hotels of various sizes that were located in the geographical area of Hamburg, Bremen, Dusseldorf, Frankfort, Karlsruhe, Mulhouse, Basel, Munich, and Berlin. The heating contrivances described herein were found in the average billet and German home and do not represent oddities. Whether they are used now is questionable; each person is rationed to 50 lb. of coal a year.

During the war years, the sale of hot water appliances was controlled solely by a hot water trust association sponsored by the Reich, and such appliances and apparatus were manufactured and sold strictly on a ration basis, the Reich having priority on all hot water apparatus for military purposes and for new housing projects. Many new row- and apartment-type houses were constructed in areas that were heavily damaged during the early part of the war, and all these residences required hot water apparatus and equipment.

Domestic Fuels

The chief fuels which were utilized by the Germans in heating hot water for domestic use were wood, coal, propane and artificial gas. The latter two fuels were extremely expensive and were considered a luxury when used for heating water. In rural communities, where wood was scarce and coal difficult to transport, propane was used by the more prosperous agricultural population in the Junkers small instantaneous-type heaters. Whenever possible, coal was the principal fuel used to heat water in the common residence; coils were generally located in the house heating furnace for the winter's hot water supply. In the summer, a small bucket-a-day stove furnished the household hot water. In large apartment houses in Hamburg, for example, the hot water for general domestic use as well as for bathing was supplied through central heating systems. Such systems for a central supply of hot water had been designed by Rud. Otto Meyer of Hamburg and were used in recently constructed apartment buildings, as many as ten buildings grouped

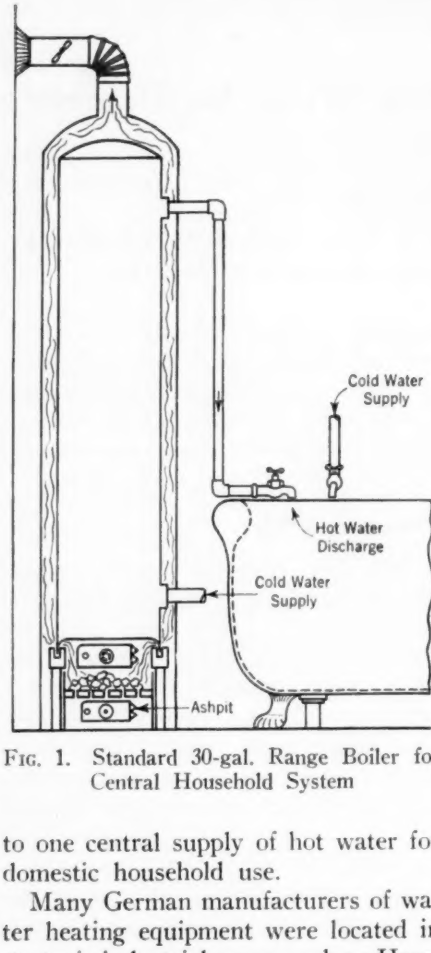

FIG. 1. Standard 30-gal. Range Boiler for Central Household System

to one central supply of hot water for domestic household use.

Many German manufacturers of water heating equipment were located in strategic industrial areas, such as Hamburg, Posen, Siegen and Frankfurt, and as a consequence these plants suffered heavy damage.

Hot Water Heaters

As an example of the extreme in a central houshold hot water supply system, a lodge on the outskirts of Essen heated water for bathing purposes by means of a standard 30-gal. range boiler, illustrated schematically in Fig. 1. The external area of the standard range boiler was jacketed with a rolled ornamental shell which provided an enclosure for exhausting the products of combustion from briquetted coal. Coal briquettes were charged on the grate in the upper door and the ashes were removed by means of the ash pan which was located inside the lower door.

One means of heating water for domestic laundering is shown in Fig. 2, which was originally sketched in the basement of a row house in Hoechst. These houses were recently designed by the architectural section of the I. G. Farbenindustrie, and each house had an individual heating plant for household hot water, but in spite of this a laundry tub of this design had been in actual use. It consisted of an enameled tub in cast-iron shell, heated directly by briquetted coal.

In heating water in relatively small household quantities for making ersatz beverages, washing dishes and cooking vegetables, the housewife generally used either a small gas range without an oven or a coal stove with an oven.

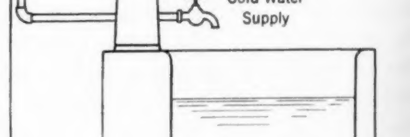

FIG. 2. Domestic Laundry Tub Using Briquetted Coal

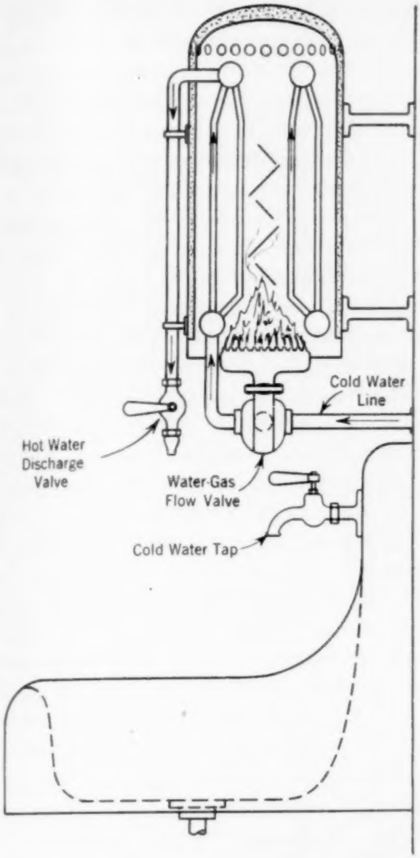

FIG. 3. Junkers Instantaneous Heater

The choice between gas and coal fuels depended on the time required for heating or the amount of water to be heated. In the average house, a coal and a gas stove were used interchangeably. A rectangular receptacle is brazed to the coal stove top over the baking oven, and water from this container was used only where limited quantities of hot water were needed, such as preheat water for cooking vegetables by gas, for hot beverages and general washing purposes. Such combinations of gas-coal ranges were prevalent throughout Germany.

Instantaneous and Automatic Heaters

One of the most popular types of water heaters, extensively installed in some apartments, homes, small hotels and garages, was the Junkers instantaneous heater. These heaters were manufactured for the most part by Junkers in the vicinity of Posen. Heater units of this type were fabricated to sell at a low price and were installed at the source where hot water was required, such as above the kitchen sink or the bath tub. The unit was completely automatic in that hot water was delivered instantaneously in a usable volume by merely opening the hot water hand valve. A section of a Junkers heater is illustrated schematically in Fig. 3. Basically, the heat exchanging unit consisted of two tubular headers to which were connected multiple copper tubes aligned in parallel. A water-gas flow valve was con-

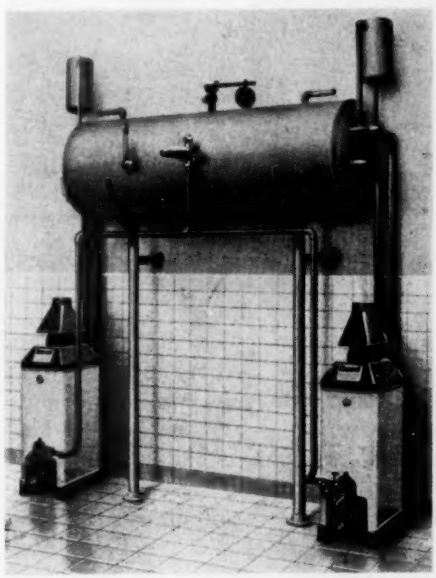

FIG. 4. Ruud Automatic Double Heating Unit and Storage Tank

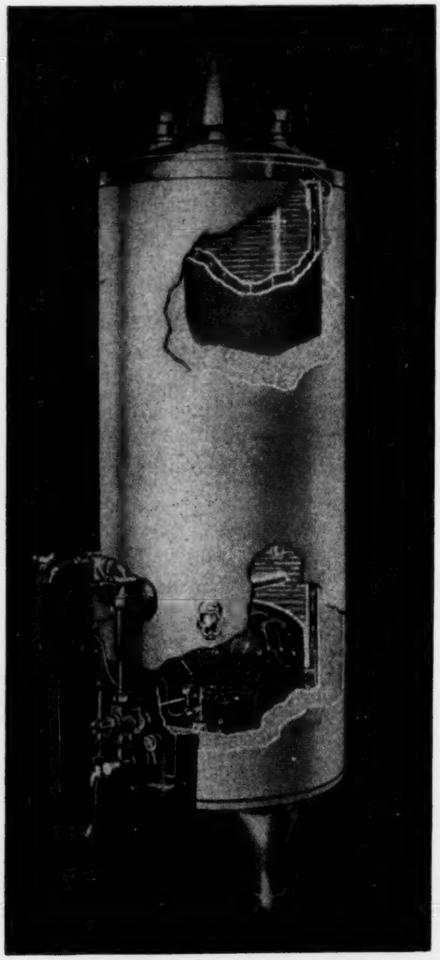

Fig. 5. Ruud Automatic Storage Unit Heater

nected in the cold water supply line for the purpose of providing a flow of gas to the burner when a drop of pressure occurred in the cold water line, upon the opening of the hot water discharge valve. This type of heater was well constructed and it was reported that the maintenance on these units was extremely low for the high heating efficiencies that were developed. Both artificial and propane gases were used as fuels for these hot water heaters.

One of the companies that manufactured the automatic storage unit heaters in Germany was the Ruud Company in Hamburg. Prior to and during the war this company produced approximately 100 hot water storage units per month. The manager of this company said that the demand for this type of hot water heater was not very great in Germany because of the general expense involved. In size, shape and design the unit closely parallels the American types in general construction. This type of automatic hot water storage heater was considered expensive to operate because of the high cost of gas and the alleged inefficiency of storing hot water. During the war, most of these units were sold directly to the Reich for installations in hospitals and other institutions. Figure 4 illustrates a double heating unit connected to a galvanized hot water storage tank, and Fig. 5 shows one type of Ruud automatic heater. A built-in feature of these heater shells constructed by the Ruud Company was the side clean-out hole. It was discovered by the Ruud

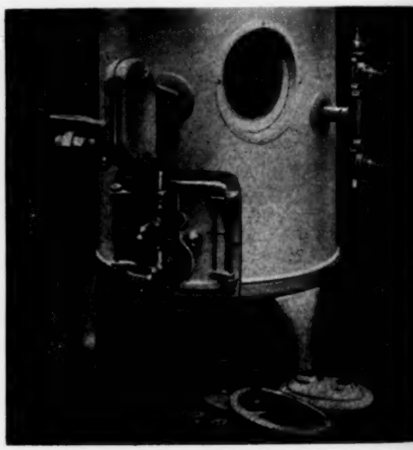

Fig. 6. Ruud Automatic Heater, Showing Side Clean-Out Hole for Sludge Removal

Company that during the life of the heater shell a considerable quantity of sludge collected on the bottom, especially a bottom that was convex to pressure, and reduced materially the heating efficiency of the burner. In order to maintain a uniform efficiency, this particular company provided a hand-hole clean-out so that the deposited sludge could be periodically removed from the bottom of the heater shell. Figure 6 illustrates the location and construction of the hand-hole clean-out. During the war only galvanized heater shells were used in these units because of the scarcity of copper and nickel.

The heating of water for domestic use was a considerable expense in the German household budget and every means was used to provide it as economically as possible in spite of the time, inconvenience and labor required to produce it.

Control of Cross-Connections

By L. E. Wickersham

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Presented on April 2, 1946, at the Indiana Section Meeting, Lafayette, Ind.

CROSS-CONNECTIONS between the system of public water supply and water lines of a secondary source of unknown or questionable quality is a subject of vital concern to those responsible for the management and operation of water works. Much has been published and many discussions have been held heretofore on this important topic. Needless to say, all appreciate that an adequate supply of safe and wholesome water is essential for the well-being of the consumer and for the protection of the general health of the community served.

The measures required at the water works plant to produce and put a safe water supply into the distribution system are well known. Despite all the precautions taken to safeguard the supply at the source, however, the likelihood of contamination of the water from points along the system is very real. It is readily understood that if a supply is to remain within the limits of standards for safe and potable water and is to meet the accepted bacteriological standards, it must be distributed in lines entirely safe from outside influences that might create a situation dangerous to public health.

Numerous investigations have been made in years past and conclusive evidence has been obtained showing that cross-connections with unsafe private water supplies and back-siphonage of waste waters, due to improperly installed or designed plumbing fixtures, have been responsible for pollution of public water systems. There are records of such cross-connections and inter-connections resulting in outbreaks of water-borne disease. Although the statistics of such infections, as compiled by Gorman and Wolman (1), have been referred to many times, it seems desirable to review the figures again as a reminder that the ever-threatening danger of back-flow of contaminated water into the distribution system still exists in many places. During the years 1920–1936, 54 outbreaks of typhoid fever, dysentery and associated disorders, affecting some 11,000 persons, were reported in the United States and Canada. Of this number of outbreaks, 49, or 91 per cent, were attributed to cross-connections with polluted water supplies.

For years public health associations and sanitary engineers have been cognizant of the health hazards resulting from cross-connections, both direct and indirect, and most of the state boards of health have formulated rules and regulations governing their control.

Methods of Connection

In direct cross-connection, the public supply is separated from a secondary supply merely by one or more gate valves, or by a more protective ar-

rangement, such as double check and gate valves. Such connections are quite common at industrial plants, office buildings, theaters, hotels and a number of private dwellings, where a secondary supply is utilized entirely, or in part, for processing, cooling, boilers, condensers and in many instances for drinking and toilet purposes. The indirect cross-connection arises when the supply outlet to any plumbing fixture, solution tank, swimming pool, sewage disposal equipment, hospital appliance or the like is submerged in contaminated waters or wastes, and when it is possible, under certain hydraulic conditions, for these wastes to be back-siphoned if a vacuum is created in the city main.

Provision for use of either or both the public and secondary supplies at the same time may be had without resorting to a cross-connection. The public water supply can be admitted into the storage tank or sump for the secondary supply through a point of discharge above the maximum high-water line in the tank, or by means of a swing-ell or suitable four-way valve if large storage of water from the tanks on the private system or in the private supply lines is not provided beyond the location of such a device.

Inadequacies of Separation

When a complete separation of the two water supplies by independent lines is made, it is natural to expect that ample protection will be afforded. This assurance, of course, is dependent entirely on the continuity of separation. There have been occasions in which workmen, through carelessness or ignorance, have made cross-overs constituting cross-connections, by the insertion of a pipe or the coupling of a hose line. Usually these errors are made without the knowledge of those in charge. Realizing the dangers involved, the managements of some industries have adopted schemes for marking the different piping throughout a plant in different colors to reduce the possibilities of error.

About a year ago, the author conducted an investigation of an outbreak of gastro-enteritis resulting in four cases of typhoid fever among employees of a large industry. This concern obtained a portion of its supply from private wells and a surface stream, reusing this water a number of times, after aeration, for cooling and other industrial purposes. In addition, the public water supply furnished by one of the American Water Works and Electric companies was used for drinking throughout the plant, as well as for fire protection and certain other uses.

According to the plant manager and the assistant chief engineer in charge of water distribution, the pipelines for each supply were entirely separate and without cross-connection. Yet it was discovered that at least three cross-connections existed, two in the boiler room and another at the fire pump. It was also found that both supplies were piped independently into a number of the lavatories, where the public supply was used in the wash basins and the non-potable supply was provided for flushing toilets and urinals. Although no cross-connections were in evidence between the two exposed pipelines within these quarters, it would have been possible for the lines to have been cross-connected at some other point, since most of the water lines were extended underground through tunnels. A large number of the pipelines were carried through

these passageways, some of which were barely large enough for accessibility, to various points in the plant. Undoubtedly this was a dangerous arrangement of the piping layout, and it would have been easily possible for some irresponsible person to make a connection to the wrong water line.

The concern was ordered to eliminate all cross-connections immediately, and was advised to paint all exposed water lines throughout the plant, using a different color for each supply. At the time, fortunately, the pressures in the city mains at the points of connection to the industry's potable water line were in excess of those maintained by the industry in its non-potable water supply system, and no waterborne illness was reported outside the company's property. This outbreak is similar to the occurrence of gastroenteritis recently reported (2) at an industrial plant in a small town in Indiana.

The precautions now being taken to insure safety of the public water supplies no longer permit, as good practice, any new connections between public and secondary supplies. The day has passed when the statement, "We have used the water from this well for many years and no one has had typhoid fever yet," is all that is necessary to qualify such secondary water as a safe and potable supply.

It is true that many wells when drilled in a suitable water-bearing stratum, remote from sewer lines or other possible sources of pollution and properly installed and protected, can produce safe water. Assurance of the quality, however, can be had only by regular, periodic bacteriological examination. Generally the water company does not know the results of the analysis of such private supplies unless the analytical work is being carried on under its own direction. In investigating many cross-connections, the author has found that the owner often has little or no knowledge of the bacterial quality of his well water, although in many instances this supply is used for drinking by his employees.

The danger from admission of surface water through well seals that are insecure or non-existent, or from underground pollution seeping through old, pervious casings, is well known. The former condition is readily detected but not always corrected. The latter, however, may exist and not be discovered unless ascertained by chemical or bacteriological analysis.

Protective Regulations

Those engaged in the water works business must keep in mind their moral as well as legal responsibility to maintain a safe water throughout the system, and be on the alert against health hazards. In recognition of these responsibilities, the more than 70 operating companies in the American Water Works and Electric Co., Inc., system recently adopted new rules and regulations on cross- and inter-connections. These regulations, which have been published in the JOURNAL (3), were devised after much study and deliberation, primarily to establish a uniform practice to be followed by all companies in dealing with such matters. They oppose all cross-connections absolutely, permitting only a tie-in with another public water supply that has been approved by the state department of health. The policy now in effect is to work toward the elimination of all other existing cross-connections and to prohibit the installation of any new ones.

It might be added that cross-connections are classified as acceptable or objectionable. To be considered as acceptable a cross-connection must be made to another public water supply approved by the state department of health and installed or continued with the knowledge and consent of the company. An "objectionable cross-connection" is any other than an "acceptable cross-connection." Certain existing cross-connections with private well supplies which do not constitute a substantial threat to public health are considered "tolerated cross-connections."

The new rules contain provisions authorizing discontinuance of service to premises on which there exist cross-connections which are neither "acceptable" nor "tolerated" within the definitions of those terms or on the orders of the public health authorities or recommendations of plumbing inspectors.

Procedures are established under which the existence of tolerated cross-connections may be continued provisionally, without discontinuance of service, on recommendation of the company's sanitary engineer. Installations of any new cross-connections are prohibited.

Before the adoption of these rules and regulations, the author conferred with J. L. Quinn, who at the time was acting in the capacity of Chief Engineer of the Indiana Board of Health, to acquaint him with the policy proposed. Approval of the adoption of these rules and regulations by the four American Water Works and Electric companies operating in the state was obtained from the Indiana Board of Health and the Public Service Commission of Indiana. These rules are now in effect and enforcement is under way by the Indiana companies.

Just prior to the adoption of these rules and regulations, a representative of the Board of Health made a survey of the cross-connection situation at Terre Haute, Ind., and, in compliance with Article 2 of the Board's Rule SE–9, "Regulating the Installation and Maintenance of Physical Connections Between Public Water Supply Systems and Other Water Supply Systems," ordered the management at the various industries to proceed immediately with the installation of approved check valve assemblies.

As sanitary engineer for the water company, the author spent ten days last fall at Terre Haute, some six months after the survey of the State Board of Health, and made an inspection of all the private well supplies cross-connected with the public water supply system. An inspection report covering pertinent information and a diagrammatic sketch of the piping layout and location of wells, tanks and the like was prepared, showing the approximately forty cross-connections.

The policy of the water company and the rules and regulations were explained to the officials. In signing the application for continued service the customers accepted responsibility for the continued existence and operation of the cross-connection and assumed all liability for any harm which may come through the use of the supply. At the time of the inspection, samples of water were obtained of the private supply for bacteriological analysis at the water company's laboratory. It might be mentioned that it has been the practice for some years for the Terre Haute Water Works Corp. to examine each of the supplies regularly twice a year, and the results of such tests have been furnished to both the Board of Health and the New York

office of the company. This procedure is to be continued.

The bacterial quality as evidenced by future tests along with a study of reports of the semi-annual inspection of the protective devices, required by the Board of Health, will to a large extent determine whether the protection given by the check valve assembly on the cross-connection warrants continuation of service.

In accordance with the new rules and regulations, it is required that the sanitary engineer for the water company examine all applications for continuance of water service and review drawings of the cross-connection layout accompanying the application. On a basis of examination, studies and inspection, and relying upon the accuracy and truth of the representations made by the applicant, the sanitary engineer either recommends continuance of service or the discontinuance of service until the cross-connection is broken. Before any action is taken on the application, an inspection of each cross-connection is made either by the company's sanitary engineer, an assistant or a trained representative of the local water company; and a report is prepared on a company form. At the same time samples of the private supply are collected for bacteriological examination in the water company's laboratory. The tolerated cross-connection will be permitted only so long as the bacteriological tests show the secondary supply to be safe for drinking.

It should be emphasized that elimination of cross-connections and their hazards will finally come only through the co-operative efforts of the water utility and the state and local health authorities, in conjunction with education of the customers.

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Stop Those Nuisance Charges!

By Earl E. Norman

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Presented on May 8, 1946, at the Annual Conference, St. Louis, Mo.

PERSONS in public office must meet the public with a smile and a certain degree of tact or they do not stay in public office. Nevertheless, behind the pleasant front, many official practices and many of the rules and regulations applied to the public are irritating beyond all measure. Some of these actions are dogmatic, arbitrary or even despotic. Too many public administrators think that, because they hold public office, they are exceptions to the rules that apply to business in general. They set themselves on pedestals, and sometimes consider the public so little that they come back to earth, jobless, before they know what has happened.

Strict Logic or Good Business?

A noteworthy public irritant practiced by some utility systems is that of making extra charges for incidental or extra services. These charges are usually based on some punitive or economic reason which, when analyzed dispassionately and factually, can often be justified. Nevertheless, they irritate the customer and make him take an unfavorable or even antagonistic attitude toward the utility. If the customer would present his grievance to the utility management and give the utility a chance to tell its side of the story, he would often be pacified. But he does not do that. He merely pays and grumbles—not only to himself, but to his friends and neighbors. In fact he grumbles to everybody *except* the utility management—and the utility has no chance to defend itself.

Does a grocery store charge for opening an account? Yet many water utilities charge for turning on water. If a customer's payments are slow, a retail store may refuse further goods on credit; but when the customer has paid all arrears, does the retailer charge a dollar to start serving him again? Yet most utilities charge a penalty to re-establish service after a delinquent turn-off. If a delivery truck breaks down, does some purchaser, to whom goods were being delivered, have to pay for repairing the truck? Yet almost all water utilities require the customer to repair, at his expense, any failure or break in his service connection. Every one of these charges can be technically and economically justified, yet ordinary competitive businesses make no such "nuisance charges." The costs associated are merely overhead costs that the business must absorb.

It may be argued that if these charges are not made, the public will abuse the privilege and overhead will soar. But is this true? It has not been the experience in Kalamazoo, Mich., where no nuisance charge of any kind has been levied for more than eight years.

Overhead expenses have increased very little; there has been no abuse; and the little increase in overhead has purchased, as value returned, a great deal of good will.

Common Nuisance Charges

Twelve different nuisance charges can be listed as having been used at one time or other by various utilities:

1. *Turn-On Charge.* It certainly costs money to turn water on, whether to open a new account or to restore a delinquent's service. But it is felt that a delinquent customer is penalized enough by discontinuance of service. Without the charge, the utility no longer has to face the accusation, "You turned it off just so you could charge me a dollar to turn it on again." The Kalamazoo utility has found that the money formerly collected for this service irritated customers beyond all value received. There has been no increase in delinquent "turn-ons" since the utility stopped making this charge.

2. *Turn-Off Charge.* When a customer is charged a dollar (or any other sum) for turning off water, he is being invited to leave the premises without the utility's knowledge. It is difficult enough to keep up with customers as they move, without encouraging them to do so secretly.

3. *Trip Charge.* The theory of the trip charge is that if a customer is delinquent in the payment of a bill but offers to pay the "turn-off man," the turn-off man can accept payment and make only that one trip to the premises instead of two separate trips, one to turn the water off and another to turn it on. Economically, therefore, the utility is justified in charging less for the one trip than it would if the water actually were turned off. This arrangement, however, invites customers to wait until the turn-off man arrives and then pay him the amount of the bill plus, say, a 50¢ trip charge. The customer does this repeatedly, but he grumbles to his neighbors about the "trip charge." It is altogether an undesirable practice.

4. *Meter Purchase.* A very common requirement among water utilities is to charge the consumer for his meter. So far as the author has learned, it has never been used in any other utility. There is no more reason for requiring a water customer to purchase a water meter with which to measure the commodity he buys than there is for a grocery store customer to pay for the scales on which the grocer weighs the sugar. To require a water customer to purchase a water meter is one of the most vicious practices in which a utility can indulge. In Kalamazoo, meters have been furnished as a part of the cost of doing business for nearly twenty years.

5. *Meter Repair Charge.* The author believes that the same logic applies to charges for meter repairs as applies to the original purchase of the meter. The customer is not at fault if the meter fails; there is nothing he can do to increase or decrease meter repair costs. That is strictly a utility problem and it is the utility's business to see that meters are kept in good working order. Although it is more or less to the customer's advantage to have the meter stop, he should not be charged with any responsibility for meter repairs unless he actually abuses, breaks or molests the meter.

6. *Hot Water Charge.* If the customer is careless and allows his water heater to run longer than it should, hot water will back up into the meter, damaging it. It is quite common to charge the customer for repairing this

damage, and certainly it is the customer's own carelessness that caused it. Nevertheless, the author believes this is just another nuisance charge. At Kalamazoo, where no charge is made, the practice of warning customers against repeated occurrences has been found sufficient. The city does not guarantee that it will continue making no charge if the customer does not heed the warnings, but so far, restoration of the charge has not been necessary.

7. *Frozen Meter Charge.* This charge is similar to the one just mentioned, and has been discontinued for the same reasons. Paid advertisements are placed in the local newspaper during extremely cold weather, making use of the Association's familiar "Willing Water" cartoon to warn customers that they should protect their meters against freezing, and there has been relatively little difficulty.

8. *Meter Rent.* Some water utilities have indulged in the practice of charging rent on a meter. Although the utility has made the initial capital investment in it, this appears to be just as illogical as the other meter charges. Rental charges in this sense, however, should not be confused with the demand or service charges dependent upon the size of the meter. The latter practice, as used in utility rate schedules, is often justified.

9. *Meter Test Charge.* It is quite common practice among water and other utilities to charge the customer for the privilege of having his meter tested if he believes it to be inaccurate. This is perhaps one of the most logical of all of the nuisance charges. The Kalamazoo utility, however, has eliminated even this charge, and controls the abuse of the privilege by requiring that the customer or his representative be personally present at the shop when the meter is tested. If it is not worth his time to do that, it is not worth the utility's time or expense to perform the test.

10. *Charge for Inspection of Service Connections.* In cities in which water service connections are installed by private plumbing contractors, it is of course necessary to inspect these services to see that they meet the requirements and specifications of the water utility. The inspector's time is not the only expense involved, however, for the contractor must plan to have the ditch open and must await the arrival of the service connection inspector. This is a cost which someone must bear. Obviously, the customer bears the cost in the end. The Kalamazoo utility has eliminated this expense by installing its own service connections from main to meter.

11. *Service Conection Repair Charge.* One of the most common and, in the author's opinion, one of the most illogical of the nuisance charges is that for service connection repair. When a customer is required to repair his service connection at his own expense, a typical telephone conversation explaining the requirement sounds like this:

Customer: "There's a leak in my yard."

Water Clerk: [*In a very sweet voice*] "What is your address please?" [*The water clerk, if she is smart, always asks for the address before giving any further information. If she does not, the customer is likely to remain unidentified.*]

Customer: "235 South Smith Street."

Water Clerk: "Well, Mrs. Jones, that is something which you must have repaired by your own plumber. Your

water department does not make such repairs, nor is it responsible for them."

Customer: "Well, it's none of my business. The water can keep on leaking as far as I'm concerned; I'm not going to spend any money for it. I thought you would like to be told but if you don't, good-bye."

Water Clerk: "Just a minute, Mrs. Jones. I'm sorry, but if you do not have that leak repaired within a reasonable length of time, we will be obliged to discontinue service."

Customer: "Well, my husband is a mechanic; he'll make the repair himself."

Water Clerk: "I'm sorry, Mrs. Jones. Our regulations require that the repair be made by a licensed plumber."

Customer: "All right. We'll do it, but you'll never have another report from us or from our friends. You're just in cahoots with the plumbers." [*There is a resounding click as the receiver is slammed on its hook.*]

The Kalamazoo utilities have assumed the repair and maintenance of all service connections, both those installed long ago by plumbing contractors and those installed by their own forces during the past ten years. It is felt that no one should be more interested in the maintenance of a service connection than a water utility. It is directly to the water utility's interest to see that proper materials are used and that leaks are reduced to a minimum. In fact, there appears to be no difference between the maintenance of water service connections and the maintenance of water mains; it is the utility's job to furnish water to the discharge nozzle of the meter with no expense to the customer.

In 1945, the elimination of this nuisance charge cost the utility some 60¢ per customer per year, but the many letters of commendation received for doing this work are clearly indicative of the good will value of this measure.

12. *Liens Against Property for Water Bills.* The lien system of water bill collections is another of the common unreasonable practices of water works. Many water utilities think they cannot exist if they cannot hold bills against property. The Kalamazoo utilities held bills against property as liens until about ten years ago. It was then decided that if the utility could not collect a water bill from a tenant who moved, the owner of the property should not be expected to do so. Of course, the utility has to be careful about credit; and from people whose credit is not established a cash deposit is required to guarantee payment of future bills.

The Kalamazoo water utility has approximately 15,000 customers, and the metered water sales amount to about $235,000 per year. The customers' deposits on hand to guarantee payment of bills amount to about $1,700, and there is charged off as uncollectible an average of about $250 per year, or about $1 per $1,000 of revenue derived from water sales.

Perhaps the deposit required to guarantee payment of bills should be considered a nuisance charge. Nevertheless, the utility receives very little complaint from prospective customers, who are paid 3 per cent interest on such deposits. This is a higher rate of interest than the utility would have to pay if it were borrowing money at the bank, and it is higher than the customer could obtain on his own bank deposit, but it is another good will gesture. After the customer has established credit for three to five years, the deposit is refunded with interest.

Summary

The author believes it is the utility's business to sell the commodity which it produces, to charge a proper rate for that commodity and to include in that rate all of the necessary overhead expenses of doing business, without making any extra charges whatsoever. It may appear that the overhead, under such a plan, would necessarily be extremely high. Yet the water rates in Kalamazoo have the reputation of being very low. An average of 7½¢ per hundred cu.ft. is received for all water sold, and the water utility is entirely out of debt, as is the entire city, exclusive of the school system. The water utility, in fact, has a reserve of $637,000 in cash and government bonds, after paying the city government over $82,000 per year, or 27 per cent of the gross income, in taxes, rentals and the like.

From an economic standpoint, then, nuisance charges can be stopped. Moreover, from any business viewpoint, they should be stopped, for nuisance charges simply are not worth what they cost. "And they cost plenty."

DISCUSSION—*John W. Pray*

Mgr., Munic. Utilities, Fort Dodge, Iowa

Apparently the author has been in the water works business long enough to be able to see this important utility service from the customer's point of view. It surprised this writer to find that apparently there are others who share his opinion of these so-called nuisance charges. All will agree that it is the job of water works men to render the best possible service at the lowest possible cost, especially if the plant is municipally owned. This writer believes that the more charges are confined to the actual product being sold, the more satisfied customers will be. At times he has been disgusted with himself and his business while arguing with some irate customer over some minor charge, the aggregate of which would mean virtually nothing to the utility in any year. For this reason, over a number of years, a number of these non-production charges have been eliminated at Fort Dodge. Others have never been used. Now there is only one such charge, and that may be at least partially dispensed with in the near future.

Fort Dodge, Iowa, has a population of 23,000. It has 70 miles of mains, 5,500 customers, average annual receipts of $96,000, an average overall return of 11¢ per 1,000 gal. and a 7¢ per 1,000 gal. cost of production. The utility's attitude toward each of the nuisance charges listed by the author can be very briefly discussed:

1, 2. *Turn-On and Turn-Off Charges.* It is true that it costs money to turn on or turn off water for any purpose, but this charge was eliminated long ago. It is the utility's policy to avoid turning off water for non-payment just as long as possible and to try to judge every case—there are only a few—on its own merits. Emergency turn-offs are made day or night without charge.

3. *Trip Charge.* The utility has never seen the need for a trip charge. No doubt a considerable amount of time

is used and a good many miles are covered for which some charge could be made, but the utility has not felt the need to do so, and therefore has never made such a charge.

4. *Meter Purchase.* Prior to 1936, the customer was required to purchase the meter. At that time, the water department began to furnish all new meters and replacements, as well as all maintenance except repairs occasioned by negligence of the customer. The public accepted this change, and there were no claims for meters which had previously been paid for by customers.

5. *Meter Repair Charge.* The cost of all meter maintenance and repairs is borne by the water department except as stated above. Repairs required because of negligence on the part of the customer are charged to him at cost.

6. *Hot Water Charge.* Damage to a meter, when caused by hot water, is definitely the responsibility of the customer, but the charge has been eliminated at least for the first occurrence. The circumstances are explained to the customer, and he is warned that future occurrences will be charged to his account. There are so few repeat cases—sixteen during the past year—that they are no particular problem.

7. *Frozen Meter Charge.* What is unfortunate about this charge is that it is usually made against the customer who is the least able to pay. The utility feels it is a customer responsibility, however, and still bills him for the cost of the repairs. It also advises him how to protect his pipe as well as the meter against freezing. During the past winter, of average temperature, there were 87 frozen meters.

8. *Meter Rent.* The utility sees no logical reason for meter rent and has preferred to set up a rate covering this cost and other nuisance charges.

9. *Meter Test Charge.* The Fort Dodge, Iowa, utility is in complete agreement with the author on his method of handling meter tests. It will make a test for anyone who will come to the shop to see it, but on no other basis. Of course, all meters in the shop are tested before being sent out.

10, 11. *Inspection and Repair of Service Connections.* The service connections situation is not ideal. Plumbers install all services from the main to the building and the cost of installation, as well as all maintenance and repairs, is borne by the customer. The water department, of course, requires certain types of material to be used, specifies just how they shall be installed, and makes an inspection without charge to see that these specifications are followed. The department makes all taps and still charges a small fee for this. It is this writer's opinion that all services should be installed and maintained at least to the street line by the water department.

12. *Liens Against Property for Water Bills.* It has never been the practice in Fort Dodge to use liens against property to collect bills. The department believes its job is to make collections on the account before any necessity to file a lien arises, and its bad-debt losses are so small that this resort would not be worth the effort. A deposit is required from tenant customers, but no interest is paid on the deposit.

The water works utility in Fort Dodge has a valuation of $1,850,000; has been entirely out of debt for many years and usually has a reserve in excess of $100,000; has no levy and pays into the general fund of the city from $10,000 to $20,000 a year (which

amount comes largely from the operation of a small hydro-electric plant); and furnishes water to all city departments without charge. Rates are comparatively low, and it is believed that overhead is not materially increased by the elimination of most of the nuisance charges mentioned by the author.

DISCUSSION—*R. W. Esty*

Supt., Water Dept., Danvers, Mass.

Nuisance charges and policies are so common that all water works operators should review their own practices and perhaps do a little housecleaning. Removal of these charges benefits not only the customers but the utility as well.

At Danvers, Mass., the Water Dept. used to add a 25¢ summons charge to overdue bills, antagonizing the customers so greatly that at length the charge was discontinued. Even the method of charging for water—according to fixtures rather than consumption—was troublesome, and eventually gave way to metering.

At present a service or demand charge is made in addition to the meter rates, and this method seems to bring in very few complaints. In this writer's opinion, such a charge is better than the use of a minimum rate because it does not destroy the incentive to conserve water or to repair small leaks. Many families never use the amount of water allowed them under minimum rate structures, and can even use several times the amount they need before they exceed the limit. For these customers, a minimum rate tends to defeat the purpose of metering, which is to make payment proportional to consumption, and to encourage elimination of leaks and waste.

The Danvers rate is $1.20 per quarter for the service charge and 13¢ per 100 cu.ft. for water. Of the Department's 3,300 customers, approximately 60 per cent pay $12 or less each year for water. Occasionally the service charge has been responsible for some misunderstanding, but customers are apparently satisfied by the explanation they receive, for complaints are very rare. This is the closest approximation to a nuisance charge in existence at Danvers.

The Water Department owns all meters, which are set and maintained at its own expense. The customer is charged only for damage caused by freezing or hot water, and then only to impress him with the importance of protection. Without some financial penalty for negligence, the customer might never bother to guard against the trouble.

The installation of water services is made by the department, which assumes the cost of the part in the street and charges to the owner the cost of installation from the property line into the building. This policy has been followed for 70 years and seems highly satisfactory.

The department does favor the lien law, which most Massachusetts towns and cities use to collect water bills. This does not cause undue hardship to the customer. Most water utilities in the state do business only with the property owner, but property changes hands so rapidly that the lien is felt to be the only stable way of doing

business. Customers do not object to it, and in fact some even prefer having the lien applied so they can pay it with their taxes, rather than bother with a water bill four times a year.

On the whole, pleasant customer relations have been maintained. The department's policy is to meet them with a smile and send them away with a smile.

DISCUSSION—*C. M. Roos*

Mgr., East St. Louis and Interurban Water Co., East St. Louis, Ill.

In his paper, the author has referred to specific types of special or extra charges made by some public water supply systems. These charges are in addition to the established or published rate schedule for regular service, and supposedly cover the cost of special service to a customer over and above the cost for routine normal service. The author properly has emphasized that the feeling with which a customer lodges a complaint is not always governed by the amount of money involved, but rather by the apparent discriminatory, arbitrary or inequitable character of the charge. He also wisely points out that customer resentment against the utility as a result of such practices is frequently silent, but deep seated and damaging in its influence and reactions.

The day has long since passed when any business, either publicly or privately owned, can assume that, because it has a monopoly, it can ignore the opinions of its patrons and establish or follow practices which antagonize them. The objections to some of the so-called utility nuisance charges are of course primarily psychological rather than logical. Such charges sometimes are penalties for failure of certain customers to comply with entirely proper rules and regulations. In fact the reason for invoking these charges is to avoid penalizing the large majority of customers who do not violate the established rules. At best, however, the revenue derived from some of the charges is so small that even from an economic standpoint many of them are not worth the loss of customer and public good will.

To those who have not investigated the matter, the author's paper could convey the impression that nuisance charges are made as a general practice in the operation of all public water supply systems. As a matter of fact, a survey of a number of plants in the Middle West shows that most privately owned utilities and even some municipally owned water supply systems rarely, if ever, make these charges. Following is a summary of the reports received in this survey:

Privately owned water utilities

Plant A. Annual revenue, $100,000. During 1945 this company did not make a single one of the charges listed in the author's paper.

Plant B. Annual revenue, $275,000. No nuisance charges were made by this plant during 1945.

Plant C. Annual revenue, $285,000. During the year 1945 the only such charges made aggregated $59 for turn-on fees collected from 59 delinquent customers, whose services had been shut off for non-payment.

Plant D. Annual revenue, $850,000. No nuisance charge was made during 1945.

Plant E. Annual revenue, $1,750,000. Only turn-on charges were made during 1945, and these yielded $107 from 107 delinquent customers.

Plant F. Annual revenue, $1,650,000. This utility's rules provide for a charge of 50¢ for turning on service for delinquent customers. During 1945 it collected only $8 for 16 such accounts. In addition, however, this company collected from customers charges for repairing frozen meters and meters damaged by hot water aggregating $1,341.07 during the year.

Municipally Owned Water Systems

Plant A.

1. Annual gross revenue, $170,000.
2. Turn-on fees at $1 each for delinquent customers during 1945, aggregating $2.
3. Turn-on fees for renewal of service after water was turned off at the request and for the convenience of the customers, aggregating $186 during 1945.
4. A deposit-fee of $1 is required of any domestic customer who wants his meter tested. Higher fees are charged for testing larger meters.
5. Customer pays for service-line installation.
6. Customer pays for maintaining service lines.
7. Pipeline extensions are financed by special assessments, or by direct payment of cost by customers.

Plant B.

1. Annual gross revenue, $595,000.
2. Only five delinquent customers were charged for turn-on service during 1945, aggregating $5.
3. Service lines are installed at expense of customers.
4. Customers pay for meter boxes and covers and for installation of meters. Water Department furnishes meters.
5. Distribution mains are installed at customers' expense, usually by special assessment plan.
6. Customers are charged for repairs to meters damaged by hot water.
7. If meter is frozen more than twice, the customer is charged for the cost of repairs.

Plant C. Plant C is a very large and well managed system under municipal ownership. It makes no charge for turning on or off customers' general use services. Plumbers install all service lines from the main to the property at customers' expense, and customers pay the cost of maintenance. No charge is made for the meter or its installation, or for the installation of 75 ft. of street main extension per customer. For real estate developers there are special arrangements by which deposits are made to cover the cost of main extensions, with a refunding plan based upon the revenues derived therefrom. During 1945, this Department charged customers $788.85 for repairing hot water damage to meters and $389.73 for testing meters at the request of customers when the tests showed registration accuracy.

According to the records of the Illinois Commerce Commission, each of the 46 privately owned public water systems in Illinois defrays the expense for the following service:

1. Installing and maintaining service lines with all appurtenances from the street main to the curb or to the property line.

2. Furnishing, installing and maintaining meters, including boxes or vaults and covers.

3. Installing pipeline extensions in streets, highways and easements. as a direct lump sum investment in developed or built-up areas, and usually on some refund deposit basis for undeveloped areas where footage per customer exceeds the prescribed distance.

4. Repairing frozen meters.

The entire subject of nuisance charges involves some basic and fundamental principles in economics applicable to any business but particularly to a public water supply. These principles should enable those in charge of public water supply services to recognize some of the omissions and inclusions in rate schedules which frequently cause the utility's account figures to be misleading and confusing for comparative purposes.

First, as pointed out so well by the author, the total charges to customers for water and all types of service incidental to the business should be incorporated in one general rate schedule. Unfortunately, for one type of ownership, such an ideal and supposedly all-inclusive rate schedule would still include charges entirely foreign to water supply service, and, for the other type of ownership, the schedule would not include all of the costs of service, the difference being made up by what may be regarded as indirect subsidies.

For each dollar collected from its customers in 1944 by one Illinois utility, 26¢ was used to pay local and federal taxes, thus making the utility act as a tax collector under the guise of collecting for water service. In contrast, the other type of ownership not only is relieved of the requirement to include taxes in each bill rendered, but often has the benefit of a subsidy as well, in the form of free rent, or the rental value of the capital which its customers have invested in the mains and service lines making up the distribution system. In some instances also, the customers' bills do not include the cost of maintaining service lines, as the customers pay this item directly to the plumber.

The laws and mathematics of economics are inflexible and unchangeable. A charge for any service or commodity should cover its entire cost, preferably incorporated in one rate schedule which is graduated as equitably as possible, avoiding so-called "nuisance charges" and avoiding charges for items foreign to the service rendered. At the same time, at least for comparative accounting purposes, such rate schedules should not be subsidized by indirect or hidden charges which are paid by customers through other channels. Although in many instances it would not be practical to make major changes in the actual billing to customers, the accounting system should be changed to reflect the true economic status of the operation of the business.

Miracles cannot be performed by systems of bookkeeping. In the last analysis somebody must pay the cost of service or of a commodity, regardless of whose dollars are invested in the enterprise. Simply calling an item by another name, or using a different system of accounting, does not change the facts, and all of the basic facts should be reflected in the accounting records and statements of the business.

Stream Pollution Control in Indiana

By Ralph B. Wiley

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Presented on April 3, 1946, at the Indiana Section Meeting, La Fayette, Ind.

IN 1935 the control of stream pollution in Indiana was, by law, made a function of the Dept. of Commerce and Industry. Some Indiana cities had installed sewage treatment plants voluntarily and a number of additional plants were constructed through the enforcement of this law. Unfortunately the law was repealed when the Department was abolished in 1941, and no substitute was provided.

In 1943, however, a new law provided for the establishment of a Stream Pollution Control Board of six members, empowered with considerable authority. The Lieutenant Governor, the Director of the Dept. of Conservation and the Secretary of the State Board of Health were made ex-officio members, and the Governor was authorized to appoint three additional members. No more than three of the six-member board could be of the same political party. When the ex-officio members were of the same political party, therefore, the Governor was required to appoint three men of the opposite party. In 1945 the law was amended to increase the size of the board to seven and to give the Governor the power to appoint four members, no more than two of whom should be of the same political party.

In addition to the ex-officio members, the present board includes a representative of industry, a Farm Bureau member to represent agriculture and two engineers—C. K. Calvert, Supt. of Purification, Indianapolis Water Co., and the author, who is chairman of the board.

Under the provisions of the law all engineering assistance is furnished by the State Board of Health and the Secretary of the State Board of Health has appointed the Chief Engineer of the State Board of Health to act as Secretary of the Stream Pollution Control Board. This arrangement has worked out very satisfactorily.

Up to 1940, 61 Indiana cities, with a population of 1,163,007 (representing 62 per cent of the urban population), had complete treatment; 11 cities, with a population of 128,403, had primary treatment, and only 9 cities, with a population of 28,403, had septic tanks. Thus, by 1940, the sewage of 70 per cent of the urban population was receiving treatment of some kind.

In the last two years, the Stream Pollution Control Board has issued orders against 35 cities and towns having a total population of 453,095, or 24 per cent of the urban population. When all of these plants are completed, the sewage of 86 per cent of the urban population will be receiving satisfactory treatment and that of 94 per cent will be receiving treatment of some sort.

Engineers have been employed and work is proceeding in 23 of the cities against which orders have been issued.

Preliminary plans have already been submitted by 8 cities, and half of them have been approved. For one city the final plans have been approved.

Prior to 1940, 7 industrial plants and 24 governmental institutions had treatment plants; orders have now been issued against 7 industries and 1 school. Several state institutions have voluntarily begun work on plants.

The law specifically provides that the board "shall have jurisdiction to control and prevent pollution in the waters of this state with any substance which is deleterious to the public health or to the prosecution of any industry or lawful occupation, or whereby any fish life or any beneficial animal or vegetable life may be destroyed, or the growth or propagation thereof prevented or injuriously affected." The board is required "to determine what qualities and properties of water shall indicate a polluted condition."

When this latter requirement had been met, the following regulation was adopted, following a public hearing:

Whereas, the Stream Pollution Control Board of the State of Indiana has the power under Section 7, Chapter 214, Acts of 1943, to determine what qualities and properties of water shall indicate a polluted condition of such water in any of the streams or waters of this State, and

Whereas, the Board recognizes the fact that the character of all surface water is affected by the mode of life of the people and the activities of industry, and that both the people and industry are dependent on said surface water to a greater or lesser extent, and

Whereas, it is recognized that concentrations of population may exist on small streams where diluting water is insufficient to maintain suitable concentrations of oxygen by the use of known and reasonable methods of waste treatment, and

Whereas, there is a fair economic balance between cost of treatment of waste and benefits received, beyond which it is not reasonable to expend money for treatment, and the cost of treatment and the benefits to be derived must be considered in determining the extent of corrective treatment to be applied, and

Whereas, natural purifying agencies in the stream should be reasonably utilized, these agencies consisting primarily of the biology of the stream which is affected by the depth of the water, the velocity of the current, etc., and

Whereas, the necessary degree of purity of surface waters depends on the subsequent use which varies on different watersheds and at different points on the same watershed, and

Whereas, for the above-named reasons, each stream presents a separate problem and standards may need to be modified to fit specific cases,

Be It Resolved, that in general the following standards shall be applicable to all receiving waters:

1. Floating material, including grease and oil, shall not be discharged into any surface water in deleterious amounts, or in amounts sufficient to affect injuriously fish life, fur bearing or domestic animals, or the general biology of the water, or plant life in, or in the vicinity of, such water.

2. Waste which is discharged into any water shall contain nothing which will deposit in a stream or a lake to form putrescent or otherwise objectionable sludge banks.

3. Waste which is discharged into any water shall contain no materials in concentrations sufficiently high to affect adversely public health, fish life, fur bearing or domestic animals, or plant life in, or in the vicinity of, such water.

4. Generally the oxygen content of the receiving water, after being mixed with and affected by the waste, shall be no less than 50 per cent saturation. A lower concentration will be tolerated temporarily, but only so long as it is not injurious to aquatic life, and in no case shall

it fall below 25 per cent saturation.

5. Receiving waters shall be considered unsuitable for bathing if the coliform concentration exceeds 1,000 per 100 ml. (M.P.N.). If the receiving water is used as a source of water supply, a coliform density greater than 5,000 per 100 ml. (M.P.N.) shall not exist at or in the vicinity of the intake. Also in the case of wastes bearing or producing substances objectionable from a taste or odor standpoint, which are discharged into waters which are used as a source of water supply, such wastes shall be so treated as to render them unobjectionable before discharge into the stream or lake. . . .

This resolution was approved by the Attorney General and the Governor and was filed with the Secretary of State and the Legislative Bureau for publication with all other state regulations.

The law provides that a city or industry can appeal to the circuit or superior court from an order of the board. Either party can demand a jury trial. The court then has power "to determine whether said order is reasonable or unreasonable, and whether a polluted condition of any water or waters exists or is about to exist, and to affirm, modify, or wholly set aside such order, it being the intent and purpose of this act that the finding of said board as to whether a polluted condition of any water or waters exists or is about to exist is final only when so determined by the court." In every case the board must first be prepared to prove that its order is *reasonable* and, second, that all the provisions of the law have been complied with.

The first step was taken by the adoption of stream pollution standards. The board feels certain that these are reasonable, but only a court decision can settle the matter. The Ohio River Compact (binding Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Tennessee and West Virginia), which has been approved by the Indiana Legislature, provides that:

All sewage from municipalities or other political subdivisions, public or private institutions, or corporations, discharged or permitted to flow into these portions of the Ohio River and its tributary waters which form boundaries between, or are contiguous to, two or more signatory states, or which flow from one signatory state into another signatory state, shall be so treated, within a time reasonable for the construction of the necessary works, as to provide for substantially complete removal of settleable solids, and the removal of not less than forty-five per cent (45%) of the total suspended solids: Provided, That in order to protect the public health or to preserve the waters for other legitimate purposes, including those specified in Article I, in specific instances such higher degree of treatment shall be used as may be determined to be necessary by the commission after investigation, due notice and hearing. . . .

All sewage or industrial wastes discharged or permitted to flow into tributaries of the aforesaid waters situated wholly within one state shall be treated to that extent, if any, which may be necessary to maintain such waters in a sanitary and satisfactory condition at least equal to the condition of the waters of the interstate stream immediately above the confluence.

The deputy attorney general who advises the board is doubtful whether "substantially complete removal of settleable solids, and the removal of not less than 45 per cent of the total suspended solids" would be held to be reasonable in all situations in an Indiana court. Under such a requirement all cities and towns could be required to install treatment plants regardless of size or amount of diluting water. Probably this is the ideal

that the board should strive for, but it would seem better to approach the matter more reasonably and clean up the streams where there is positive evidence of pollution, rather than risk losing a case in court if the board should proceed in an arbitrary way.

The first step in any action is to secure the data upon which a board order is to be based. If samples show that the condition of the stream is below the standard set forth in the regulation, a preliminary order may be issued. Obviously such samples should be taken during periods of low stream flow. Lack of manpower and high flows during the summer of 1945 materially restricted the activities of the board, especially since the easy cases, involving the sewage of 86 per cent of the urban population, had already been settled. In the future it will be necessary for the board to collect the physical evidence that a city or industry is violating the regulations of the board before definite action can be taken. The State Board of Health was recently able to increase its engineering staff, and will thus be able to speed up pollution studies.

Col. M. E. Tennant, Deputy Attorney General, who is legal adviser for the board, has set forth the various steps to be followed under the law as follows:

1. Board serves notice by registered mail that it has originally determined fact that city has violated provisions of Sec. 8 of Chap. 214, Acts of 1943 (Sec. 9).

2. Within 15 days of receipt of said notice, city *may* file a full report showing what steps are being taken to comply, or show cause why nothing is being done, or deny the fact of violation and file a petition asking a hearing on this issue of fact (Sec. 9).

3. If hearing is requested, Board shall set date for hearing, not less than 10 nor more than 60 days after receiving petition, and serve notice of hearing by registered mail (Sec. 9).

4. Hearing is held in summary manner (Sec. 9).

5. Within 15 days after hearing, final order is issued and served on city by registered mail (Sec. 9).

6. If city fails to comply with final order within 60 days, Board may commence action for enforcement of final order in Circuit or Superior Court (Sec. 11).

Col. Tennant points out that the statute states "the city *may* file a full report . . . or deny the fact of violation," but that in most cases there is no opposition and, therefore, no hearing.

Municipalities may, if they choose, finance such projects by the issuance of "faith and credit bonds," but the law specifically provides that if:

. . . the amount of such bonds necessary to be issued would raise the total outstanding bonded indebtedness of such municipal corporation above the said constitutional limitation on such indebtedness, or if such municipal corporation, by its common council or board of town trustees, as the case may be, should determine against the issuance of direct obligation bonds, then such municipal corporation shall issue revenue bonds and provide for the retirement thereof, in the same manner and subject to the same conditions as provided for the issuance and retirement of bonds in an act of the General Assembly of the State of Indiana entitled "An act to authorize cities and towns to construct, own, equip, operate, maintain, and improve works, for the treatment and for the disposal of sewage; to authorize charges against owners of premises for the use of such works and to provide for the collection of same; to authorize cities and towns to issue revenue bonds, payable solely from the revenues of such works, and to make such bonds exempt from taxation and to make them lawful invest-

ments of sinking funds; to authorize contracts for the use of such works by other cities, town and political subdivisions, and to authorize charges against owners of premises therein served thereby and declaring an emergency," approved August 17, 1932, as amended by Chapter 187 of the Acts of the General Assembly of Indiana, 1933, approved March 8, 1933, and as amended by an act of the 79th regular session of the General Assembly, such act as amended being sections 48–4301 to 48–4323, inclusive, of Burns' Indiana Statutes, Revision of 1933, insofar as the provisions of said act, as amended, are applicable and are not in conflict with any of the express provisions of this act: PROVIDED, however, that the provisions of Section 5 of the above-mentioned act, as amended, allowing objections to be filed with the common council or board of town trustees by forty owners of property affected, and requiring the submission of the question of such bond issue and improvement to the qualified voters of such municipal corporation in certain cases, shall not apply to bond issues proposed by any municipal corporation to comply with a final order issued by the Stream Pollution Control Board under the authority of this act, and such objections and/or submission to the qualified voters of such municipal corporation shall not be authorized, nor shall the same, if had, operate to justify or excuse failure to comply with such final order.

The funds made available by the issuance of either direct obligation bonds or revenue bonds as herein provided, shall constitute a sanitary fund, and shall be used for no other purpose than for carrying out such order or orders of the Stream Pollution Control Board.

Steps have been taken to see that the entire procedure has the approval of a firm of bond attorneys, as it would be embarrassing to the board to have such bonds declared illegal because some step in the necessary action was omitted or improperly taken. All plans for sewage treatment works, including sewers, must be approved by the board.

In the abatement of industrial pollution, a difficulty arises when new kinds of wastes are produced which no one knows how to treat. Fortunately industry has come to recognize its obligations, and several research projects are now being financed by industry.

The law provides that failure to comply with the final order of the board constitutes a misdemeanor and makes the parties responsible subject to a fine of not less than $25 and not more than $100, to which may be added imprisonment in the county jail for not more than 90 days.

The board so far has received the hearty co-operation of all concerned. Frequently city authorities have welcomed orders, because they recognized that something should be done.

Services of New State Health Department Branches

By L. E. Burney

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Presented on April 2, 1946, at the Indiana Section Meeting, La Fayette, Ind.

TO give to the people of Indiana a more effective and comprehensive public health program, the Indiana State Board of Health has recently completed plans for the decentralization of activities through the establishment of five branch offices. This program of decentralization will bring closer to the people the facilities and personnel of the Board of Health. Each branch office will render service to approximately eighteen counties.

The first area to be organized covers the southeastern part of Indiana. Since January 1, 1946, a professionally trained and experienced staff of public health workers including a physician, nurses, health education consultant and engineers have been operating from a branch office located in Columbus. Southwestern Indiana will be served by an office to be established as soon as possible in Washington. The west central branch office will be located in Terre Haute. Northwestern and northeastern branches will be served respectively by offices in Valparaiso and Fort Wayne.

Advantages of Localization

Problems involving sanitation, public health education, maternal and child health and communicable disease control are problems which can best be solved at the site of origin. For example, by reason of proximity, branch office personnel will be in a better position to assist local health officials and physicians in finding cases of tuberculosis and venereal disease and in locating the contacts of known cases so that they may receive early and proper treatment.

Assignment of personnel, who for the most part will be relocated central office field workers, to serve a limited number of counties will make for more efficient use of their experience and training. Since they will be located where the health problems arise, they will be familiar with the needs of the area and the facilities available for meeting the needs. Many potential problems can be anticipated and prevented by a more efficient application of modern principles of preventive medicine and public health practices. In unforeseen emergencies, such as floods and epidemics, the community can make use of trained and experienced physicians, engineers, nurses and other technical personnel. The personnel of the branch offices, in addition to carrying out the functions of the Board of Health, will provide local health officials with advisory services and conduct educational programs designed to improve the health status of each community.

Functions of Branch Offices

The branch office, in reality, will be a small state health department and the director will be a deputy state health officer for the area. Local health officials will retain their autonomy, the branch director acting chiefly as a consultant. Local communities, for example, will receive from the branch offices expert sanitary engineering advice in relation to public water supplies and sewage disposal plants. The water supply and sewage disposal of all FHA insured houses will be reviewed. This should be done by local health departments, but since Indiana has so few full-time health departments it will be necessary for the branch offices to continue this work in order to meet FHA requirements and protect the interest of home owners.

The relationship between the branch offices and the water works profession can best be explained by specifying the services to be given by each office. The branch offices will perform the following functions:

1. *Making of all routine water supply visits and surveys.* It is hoped that there will be sufficient personnel in the branch offices to permit a visit to each public water supply once each quarter. Since the operation of sewage treatment plants has a direct bearing on the problems of some water supplies, sewage treatment plants will be visited with the same frequency. This plan will be developed after the branch offices have been definitely activated.

2. *Receiving of all routine operation reports.* It is expected that these reports will be viewed immediately upon receipt and that any discrepancies, errors or evidence of operation which is out of the ordinary will be called to the attention of the operating plant immediately. With the personnel the Board of Health has had, it has been impossible to carry out this program. When the branch offices are adequately staffed, real use will be made of the operation reports, thereby assuring a better quality of water to consumers. Water plants will soon be notified when to begin sending reports to the branch offices.

3. *Promotion of the installation of new water supplies and the extension of mains.* It is estimated that there are 75–100 towns in Indiana that do not have, but can afford, a public water supply. Concentrated effort should accelerate the rate of construction of new water systems. The board believes that ultimately every householder in the municipality served by a public water supply should take water from that supply. Naturally, the board's activities in this field will be closely correlated with the activities of the water superintendent, as it is realized that in practically all towns there are certain areas where it is not economically feasible at present to supply water.

4. *Assistance in the sterilization of main extensions.* The central office has been able to assist in the sterilization of whole new water supplies for small towns and in some instances in the sterilization of large main extensions in existing systems. At the present time, it has one large portable chlorinator and numerous small chlorinators. By having at least one chlorinator in each branch office, the board will be in a position to give quicker and better service on emergency installations which occur from time to time.

5. *Control of cross-connections.* With sufficient staff, the board hopes

to be able to control cross-connections adequately and properly. For the past 15 years there has been a regulation prohibiting the cross-connection of any secondary water supply with a public water supply unless that connection is equipped with protective devices approved by the Board of Health. The regulation further requires semi-annual inspection of each cross-connection protective device. Because of a numerically inadequate staff, the board has not been able to enforce the regulation in many places nor has it been able to make the semi-annual inspections at places where installations have been made. The majority of the work done on cross-connections has been in Indianapolis and Fort Wayne.

Recently, an epidemic involving 30 per cent of the employees occurred in a northern Indiana factory due to a faulty factory water supply. Fortunately, the public water supply system was not contaminated. Had it been, a gastro-intestinal outbreak might easily have swept through the entire town.

6. *More attention to semi-public water supplies.* The Board of Health regulations require the same quality of water in semi-public systems as is required of public supplies.

7. *Follow-up of plans and specifications approved by the central office.* Plans and specifications which have been approved by the central office will be followed up by two or three inspections during the period of construction. Because numerous minor changes made during construction may have public health significance, it is necessary for all water works men who make changes from the original plans and specifications to submit these changes to the Board of Health.

8. *Posting water systems.* As soon as the branch offices are adequately staffed, consideration will be given to the possibility of posting approved signs at the entrances of the municipalities which are served by an approved water supply. This has been a familiar procedure in Michigan and other states for a number of years. The board has refrained from posting supplies in Indiana simply because limited personnel has not permitted visits at sufficiently frequent intervals to give assurance that the "approved" sign had meaning.

Frequent visits are made especially necessary by the recent revision of the drinking water standard of the U.S. Public Health Service, which the Board of Directors of the A.W.W.A. adopted, as did the Indiana Board of Health, in October 1945. It applies, therefore, to all Indiana water supplies. Those who have studied the standard realize that it is a bit more stringent than the previous one. A water supply which does not have a history of meeting the requirements and which is not now operating in such a manner that the board is reasonably sure it can continue to meet the standard will not be given an "approved" sign.

9. *Operators' meetings.* In the future the one-day operators' meetings which have normally been held in the fall in the six districts of the state will probably be held in five districts coinciding with the areas served by the board's branch offices. The success of past meetings has been due largely to the splendid efforts of the Indiana Section of the A.W.W.A. and Purdue University. The board believes that by confining the meetings to the areas covered by the branch offices, and by continuing the close co-operative program planning, there will be better attendance and a more interesting and constructive program.

It is hoped, too, that the engineers of the branch offices can arrange to hold night meetings with water and sewage plant operators. As a beginning, these meetings will probably be bimonthly. Sewage plant men in Ohio have held monthly night meetings with great success for a number of years. As soon as the board engineers are established in the branch offices and acquainted with the various water works men, they will be in a position to develop informal night gatherings wherein there is a free interchange of information and a consequent improvement of the profession.

Functions of Central Office

Certain water supply functions will be retained by the central office of the Board of Health in Indianapolis:

1. *The review and approval of engineering reports, plans and specifications.* Surveys by engineers in the branch offices may bring out the need for major alteration and additions to a public water supply, but it is felt that the concurrence of the central office organization should be obtained before a recommendation is submitted to local authorities.

2. *Laboratory services.* Adherence to the new standard for water will require more frequent sampling in many instances. A more conscientious adherence to sampling schedules on the part of a number of water supplies will be necessary. Compliance with the provisions of this portion of the standard as well as with the provisions concerning water quality must be made for the board to give a satisfactory certification. At this time it is not known how many additional samples will be required.

3. *Assistance in the development and presentation of district meeting programs.* As in the past, the central office will continue to assist with the district meeting programs and the giving of short courses. The principal efforts of the central office, however, will be expended to maintain a reasonable uniformity in the programs presented in the different sections of the state. Its assistance will tend to prevent overlapping, permit an effective use of specialists in various phases of sanitary engineering, and tend toward the development of programs suited to the peculiarities of different areas. As already indicated, the programs themselves will be of, by and for the profession. The assistance of the central office is simply intended to simplify preparations and co-ordinate efforts.

4. *Consultation and assistance on special problems.* At the present time, the board is attempting to hire a biologist, who will be expected to spend a considerable portion of his time on stream survey work. He will be available, however, to all public water supplies throughout the state for consultation, advice and assistance on problems of a biological nature. These services should be of material assistance to some of the small and medium-sized surface water supplies.

5. *Certification of operators.* Regulation HSE No. 7 includes the following statement:

> 3. The State Board of Health shall issue annually a certificate of qualification to each qualified operator or superintendent in responsible charge of producing or delivering a safe, potable drinking water and may request the same to attend short courses or schools, whenever in the opinion of the State Board of Health such training is deemed necessary for the protection of the public health.

This clause is most important to all water works men as it will have more

or less the same benefits and objectives as a licensing law. The Indiana State Board of Health has appointed an Advisory Committee to assist in the organization of this certification program. The Advisory Committee will consist of two water works men, two sewage treatment men, one representative of Purdue University, one representative of Indiana University, and one representative of the Board of Health. The committee will recommend policies, plant classifications and operator's qualifications.

Branch Staffing and Operation

Minimum personnel for each branch office will consist of a medical director, consultant nurse, supervising nurse, health education consultant, venereal disease investigator, milk sanitarian, food and drug sanitarian, sanitary engineer and clerical help. Selected on a merit basis, all personnel will have public health training and experience and will devote full time to their jobs. The board realizes that one engineer in a branch office will be able only to scratch the surface. Its plans call for the employment of four engineers in the southeastern, southwestern and west central branches and five engineers in the northeastern and northwestern branches. The immediate employment of one engineer for each branch office, however, plus other minimum personnel will enable the board to inaugurate its new program.

It is impossible to state exactly the date when all branch offices can begin operation. At the present time, the board is remodeling quarters in Valparaiso, Terre Haute and Washington, and is attempting to select the most highly qualified personnel available. It is hoped that the extended program can be in full swing within a very few months. Considering the time saved in travel and in the inauguration of functional programs in all phases of public health, the plan, once it reaches full operation, should provide an adequate state health program at a cost commensurate with its effectiveness.

Taste and Odor Control With Chlorine Dioxide

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THE Lawrence, Kans., water purification and softening plant operators followed natural steps in progressively improving the quality of water supplied to consumers. Raw water, obtained from the Kaw River, varies widely in turbidity, hardness, organic content, algae concentration and bacterial loading. The purification problems at Lawrence are, therefore, typical of those generally encountered in producing a potable and palatable water from a polluted supply.

Conventional treatment methods have been found suitable for clarification, disinfection, color removal and softening. As illustrated in the flow diagram (Fig. 1), the Lawrence plant includes three settling units, the first of which is used for plain sedimentation. Normally, no chemicals are added ahead of this unit, but at times of severe pollution chlorine and alum may be employed to reduce the load imposed on succeeding units. The second settling unit, preceded by flash mixing and flocculation, supplies contact time for pre-chlorination, coagulation, and softening reactions. The third unit is employed for additional coagulation, settling, intermediate chlorination and partial recarbonation. Facilities are provided for final recarbonation and for the addition of ammonium sulfate in a small unit which precedes filtration.

The control of tastes and odors from organic pollution, algae, decaying vegetation, spring thaws and surface runoffs constitutes a major problem in the treatment of this supply. The problem is intensified because a dam located a short distance below the raw water intake materially reduces the flow of the river, producing a stagnant condition which allows organic solids and silt to deposit and which stimulates the growth of algae.

Control Methods Employed

For control of tastes and odors in the water treatment process at Lawrence, it has been found that the use of ammonia-chlorine, activated carbon, free residual chlorination and combinations of these measures can be used with satisfactory results under most conditions. There are times, however, when excessive concentrations of microscopic organisms are present or when unusual conditions are created by surface drainage. When such difficult circumstances are encountered, the usual methods of taste and odor control have not been employed with complete success.

During the past two years, a new corrective method for controlling tastes and odors has been developed (1). This method consists essentially of prechlorination for disinfection, followed by treatment with chlorine dioxide to

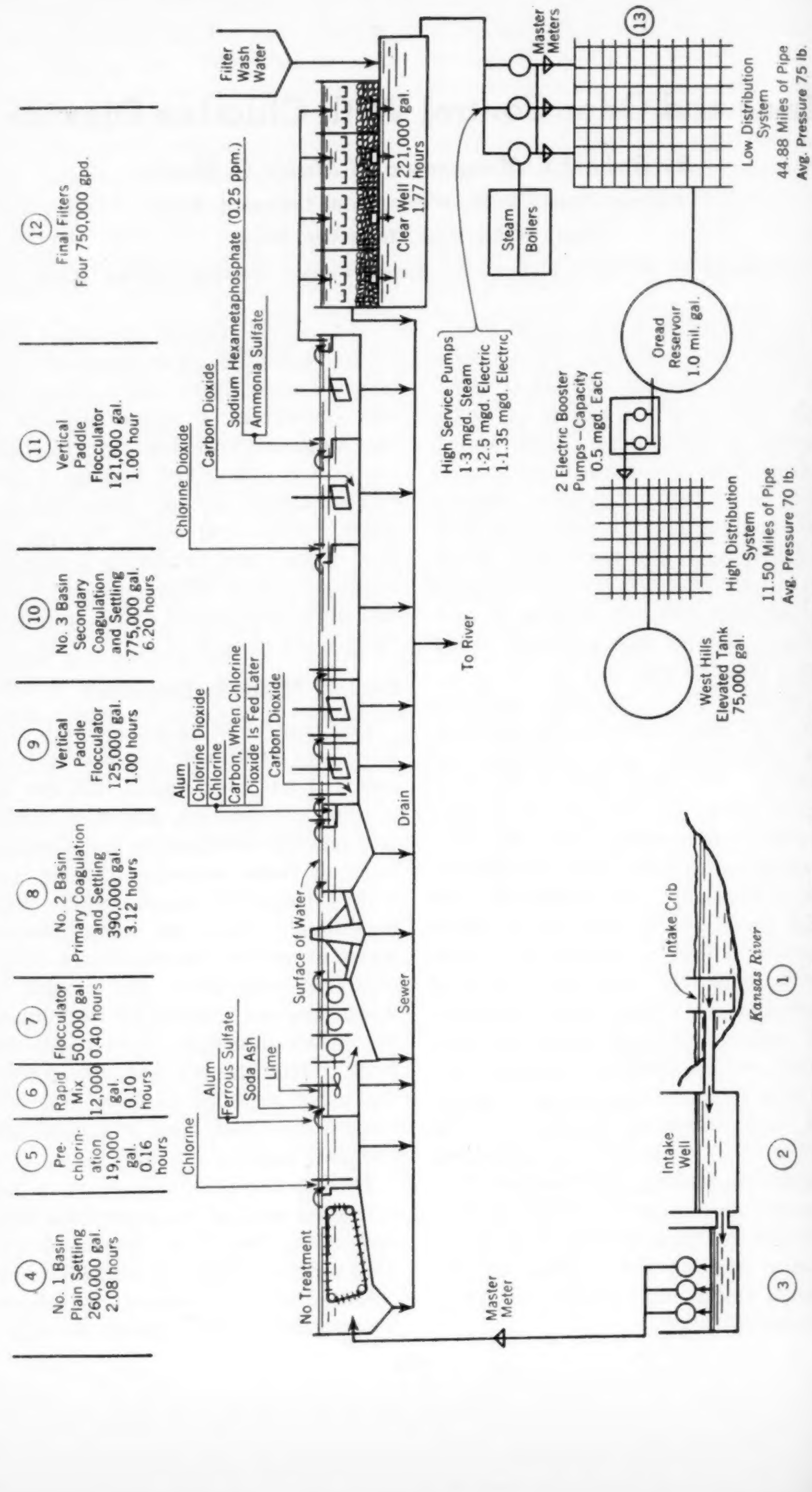

FIG. 1. Flow Diagram of Lawrence Water Treatment Plant

oxidize or destroy the organic material in algae and phenolic pollution.

Chlorine dioxide is a powerful oxidizing agent, generated by feeding a solution of sodium chlorite into chlorine water and passing the two solutions through a mixing chamber to insure complete reaction. Its oxidizing properties make it very unstable, but if the proper precautions and equipment are employed, it can be prepared for use in water treatment plants.

Chlorine Dioxide Application

It was thought that the use of chlorine dioxide might be helpful in the correction of tastes and odors from algae and organic pollution. Laboratory experimental results showed that chlorine dioxide could be used successfully for the reduction or elimination of these odors. Plant-scale experiments were then conducted after obtaining a sufficient amount of sodium chlorite and the necessary feed and mixing equipment.

The feed equipment consists of a chlorite solution barrel, a proportioning pump, a Wallace and Tiernan chlorinator, and a special glass diffuser or mixing equipment obtained from the Mathieson Co. The effluent of the chlorinator enters the bottom of the diffuser, and the chlorite solution is pumped into it a short distance above this point, thus combining the two solutions before they enter the body of the diffuser. Chlorine dioxide, the active oxidizing agent, is formed as the two solutions progress through the diffuser, and is transferred to the point of application by a rubber hose.

An amount of sodium chlorite is weighed and dissolved in a predetermined quantity of water so that each gallon of solution pumped into the diffuser gives a calculated amount of chlorine dioxide. The chlorinator is set to feed an amount in excess of the theoretical amount of chlorine needed to produce chlorine dioxide. Any excess over the theoretical amount of free chlorine serves to increase the residual in the treated water and to insure complete reaction of sodium chlorite to chlorine dioxide. It is necessary to regulate the amount of water passing through the chlorinator to keep the chlorine solution at maximum concentration. This is very important.

Treatment With Chlorine Dioxide

Treatment with chlorine dioxide on a plant scale was started August 1, 1945. The presettled water from No. 1 basin was pre-chlorinated with 1.53 ppm. of chlorine, coagulated with 6.8 ppm. of a dry mix of alum and ferrous sulfate in equal proportions and softened with 193.5 ppm. of lime. The residual chlorine content of No. 2 basin effluent varied from 0.05 to 0.3 ppm. This effluent was treated with 0.5 ppm. of activated carbon. Chlorine dioxide (0.60 ppm. available chlorine) made by using sodium chlorite at the rate of 3 lb. per mil.gal., and partial recarbonation were applied before the water entered No. 3 basin. The taste and odor were greatly reduced by this treatment although some remained in the final effluent.

The partial recarbonation reduced the pH from approximately 11.4 to 10.0. Several days later the pH was increased to about 11.0 by reducing the amount of recarbonation at this point. A marked reduction in the remaining algae taste in the finished water was noticed. Practically all taste was eliminated and only a faint odor was noticed when water was drawn into a vessel with violent agitation.

During normal operation before this treatment was started, enough secondary chlorine was added in the flocculator ahead of No. 3 basin to maintain a residual of 0.8–1.0 ppm. in the clear well. Ammonium sulfate was added in the last section of the final flocculator to convert about 80 per cent of this residual into chloramines.

After starting the feed of chlorine dioxide ahead of No. 3 basin, attempts were made to increase the excess chlorine feed through the chlorine dioxide generator high enough to maintain this residual. Even increasing this chlorine feed to 4.0 ppm. did not prevent the residual in the clear well from dropping to less than 0.3 ppm. Only by the addition of more chlorine just ahead of filtration was the residual in the clear well returned to normal. The probable explanation of this is that the addition of the chlorine dioxide to the partially chlorinated water produced a "break-point" effect and reduced the residual. This reaction could not be duplicated, however, by the addition of a like amount of "straight" chlorine.

With the chlorine feed through the chlorine dioxide generator set to feed just in excess of enough chlorine to convert all of the sodium chlorite to chlorine dioxide, the residual in the effluent of No. 3 basin dropped to less than 0.2 ppm. This residual was restored to 1.0 ppm. in the clear well by the addition of only 1.0 ppm. of chlorine in the final flocculator.

The chlorine dioxide feed was increased to 1.2 ppm. available chlorine (6.0 lb. sodium chlorite per mil.gal.), and a further improvement resulted. Activated carbon was discontinued for the balance of the month without any apparent change in the quality of the water. The average residual chlorine content in samples collected from various places in the distribution system was 0.40 ppm., and at no place was less than 0.25 ppm. Bacterial results were very satisfactory at the plant and in the distribution system, although the bacterial load of the river water was quite high.

Experiments were then conducted to find the most suitable point of application for this type of treatment. The original point of application had been in water of high pH. It was thought that a reduction in the amount of sodium chlorite used might result by changing the point of application into water of lower pH. Chlorine dioxide was then applied into the filter influent where the pH varied from 8.8 to 9.2 and also into No. 3 basin influent following partial recarbonation. Although this treatment produced a good quality of water, it was thought that better results were obtained by feeding the chlorine dioxide into water of high pH. It was also found that the excess chlorine necessary to convert all the chlorite to chlorine dioxide produced high chlorine residuals on the plant tap following application into the filter influent.

Severe Taste and Odor Problems

In September there was a large increase in the amount of algae present in the river water. Green algae, diatoms, protozoa and blue-green algae were present in large numbers throughout the month. The threshold odor of the river water varied from 24 to 60 at the period of the greatest algae growth. Free residual chlorination in the raw water was started when the supply of sodium chlorite was exhausted. Amounts as high as 5 to 7 ppm. chlorine were necessary to reach the "break point" and to maintain the normal residual of 0.8–1.0 ppm. in the

filter influents. This treatment did not produce an effluent entirely free from taste and odor due to the production of a chlorine taste compound after the application of lime for softening.

Chlorine dioxide was applied to the flocculator ahead of No. 3 basin after a new supply of sodium chlorite arrived. At the same time free residual chlorination in the raw water was discontinued. The taste in the finished water changed from a chlorine compound taste to a slight algae taste. The odor of algae was greater than the taste.

The sodium chlorite feed was increased from 6 to 14 lb. per mil.gal. of water, but even this did not produce a taste-free water. After three or four days, free residual chlorination was again resorted to in the raw water. The chlorine application point was moved to the suction line of the raw water pumps. This was followed by applying chlorine dioxide at the rate of 6 lb. of sodium chlorite per mil.gal. in the flocculator ahead of No. 3 basin. Within three days the filter effluent was taste- and odor-free. It was necessary to use free residual chlorination with chlorine dioxide until the blue-green algae season was over.

During January and February 1946, melting snow and ice created taste problems on two occasions. At these periods, neither free residual chlorination nor chlorine dioxide was being used as a normal operating procedure. The chlorine dioxide was started immediately after these chlorophenolic tastes became apparent. It was applied at the rate of 0.75–1.5 ppm. available chlorine (4–8 lb. sodium chlorite per mil.gal.) in the flocculator ahead of No. 3 basin before partial recarbonation. The tastes and odors were completely removed by this treatment.

It has been found that a better effluent can be maintained by feeding a small amount of chlorine dioxide in conjunction with activated carbon at all times rather than by depending on using chlorine dioxide only during the times of excessive tastes. This feed has averaged about 0.5–0.6 ppm. available chlorine or 2.5–3.0 lb. of sodium chlorite per mil.gal. The carbon feed has averaged 1.0 ppm.

In order to obtain the best results from a combined carbon and chlorine dioxide treatment for taste removal, primary recarbonation ahead of No. 3 basin has been applied to maintain a pH in the basin from 9.5 to 10.5. Carbon is added in the flocculator ahead of No. 3 basin and chlorine dioxide is added as the water leaves the basin. This is done to give the carbon as much time as possible to react, so that it does not absorb the chlorine dioxide. Although this means feeding the chlorine dioxide in a water of lower pH, it is found that where the tastes are not too pronounced the procedure means a saving in chemicals. When the chlorine dioxide is fed in the effluent of No. 3 basin, it is very easy to maintain the chlorine residual in the clear well. The drop in residual is not as great as when the dioxide is fed before No. 3 basin.

All work has been carried on at a rate of flow through the plant of 1.8–2.2 mgd. In the early part of June 1946, it was necessary to increase the flow through the plant from this rate to as high as 3.6 mgd. Even with this high rate, a satisfactory effluent was produced by leaving the carbon feed and the chlorine dioxide feed at their same proportional rate. The raw water at this time carried considerable taste due to algae and sewage pollution in the river.

This treatment was continued until the latter part of June, when heavy rainfall flushed out the small stagnant streams and added greatly to the organic material in the water. A satisfactory effluent was maintained by doubling the carbon and chlorine dioxide feeds.

While chlorine dioxide has not been depended upon as a disinfecting agent, it has proved valuable in this work. By its use, greater chlorine residual can be carried through the plant without a chlorine taste. This of course gives a greater bacteria kill. Some studies on bacterial concentration before and after the application of chlorine dioxide have been made in the plant. In every case, a reduction of bacteria has been noted after the water has been exposed to chlorine dioxide one half hour or more.

Chlorine dioxide treatment has been somewhat expensive to use compared with other corrective methods of treatment. The cost for sodium chlorite has varied from $2.00 to $10.50 per mil.gal. of water treated, depending upon the amount of organic pollution present. The average cost has been about $2.50 per mil.gal. The results obtained by this treatment, however, have more than justified the cost. Other corrective methods have not always produced a satisfactory effluent free from taste and odor. Chlorine dioxide treatment by itself or in combination with other accepted methods of treatment has proved satisfactory in all cases of pollution encountered thus far in the short period that it has been used at this plant. It has been a small cost to pay for the approval of consumers.

Conclusions

1. The preliminary results of chlorine dioxide treatment for Kaw River water show that it may be used successfully to combat tastes and odors produced by algae growths and organic pollution.

2. Best results have been obtained by applying the chlorine dioxide to water having a high pH. For the most economical use in chlorine dioxide, however, it is better to apply it in a water of lower pH, after the water has been exposed to a small dose of activated carbon for six or more hours.

3. Chlorine residuals cannot be maintained as easily when applying chlorine dioxide in waters of high pH.

4. The addition of chlorine dioxide after primary free residual chlorination produces a taste-free water.

5. Plant-scale results have shown that more chlorine dioxide is required to eliminate tastes and odors caused by algae than for other types of pollution.

6. Bacterial quality of the water may be improved, due to the higher pre-chlorination dosages which may be applied before the application of chlorine dioxide for taste and odor control.

7. The cost of this treatment at Lawrence, when balanced against consumers' approval, is small.

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Recording Residual Chlorine

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THE automatic measuring and continuous recording of residual chlorine in water has been the dream of water purification engineers and chemists for a number of years, and much research work already has been directed to the subject. In 1942, the Wallace & Tiernan Company loaned a residual chlorine recorder on trial to the Chicago Water Purification Division. The instrument is based on an electrometric principle involving the depolarizing action of chlorine on a copper electrode.

Although the original unit furnished had certain known limitations, it showed promise of serving a very useful purpose in control of the chlorination of water. The tests were begun at a time when nearly all thoughts and efforts were directed toward the war, and the manufacturer at first could not give it much attention. However, considerable time was spent by the city's staff in 1942 and 1943 studying the operating characteristics of the instrument in order to determine its limitations and reliability. The results of these tests were sufficiently encouraging to justify plans for extensive use of the recorders.

Three residual chlorine recorders were ordered by the city and in 1944 one was installed in each of the three South Side pumping stations (68th Street, Roseland and Western Avenue). Figure 1 is a photograph of the installation at the Roseland Pumping Station; the others are similar.

With the beginning of operation at the South District Filtration Plant in October 1945, the recorder located at the 68th Street Pumping Station was moved temporarily to the filtration plant. A fourth unit was obtained from the manufacturer for test installation in the filtration plant.

In spite of known limitations of the recording apparatus in its present stage of development, the value derived from its use in chlorination control warranted placing orders for ten additional instruments. Seven are to be installed at the South District Filtration Plant and the others at pumping stations in the water system.

Present Installations

The residual chlorine recorder installation is composed of two separate units, a cell and a Micromax recorder (Fig. 1). This arrangement makes it possible to locate the cell at almost any position in the plant and still keep the Micromax recorder at a convenient place.

One installation at the filtration plant is operating with the cell located in the plant effluent water and the recorder at the chemical control station, a distance

of 1,600 ft. from the cell. The second installation is measuring the residual chlorine of the water in one of the mixing basins almost immediately after chlorine application. The distance between the cell and the recorder on this installation is not more than 200 ft. The pumping station installations have the cells and the recorders located side by side, as shown in Fig. 1.

The Cell

Since starting the experimental work, the manufacturer has made several improvements in the cell. The latest model (Fig. 2) is a transparent lucite block having an upper and lower chamber. The upper chamber contains a solution of 2-molar potassium chloride in which a coiled strip of silver hanging from the cover, is suspended, forming one electrode of the cell. The water being tested passes through the lower chamber. Between the chambers is a section containing a hollow cylinder which extends almost to the water inlet in the lower chamber. At the lower end of the cylinder is fastened a porcelain diaphragm and over it a perforated copper plate that forms the other electrode.

The porcelain diaphragm limits the flow of potassium chloride out of the upper chamber to a very slow rate, and at the same time provides a path between the electrodes through which an electric current flows. A two-strand cable of No. 12 copper wire completes the circuit to the recorder.

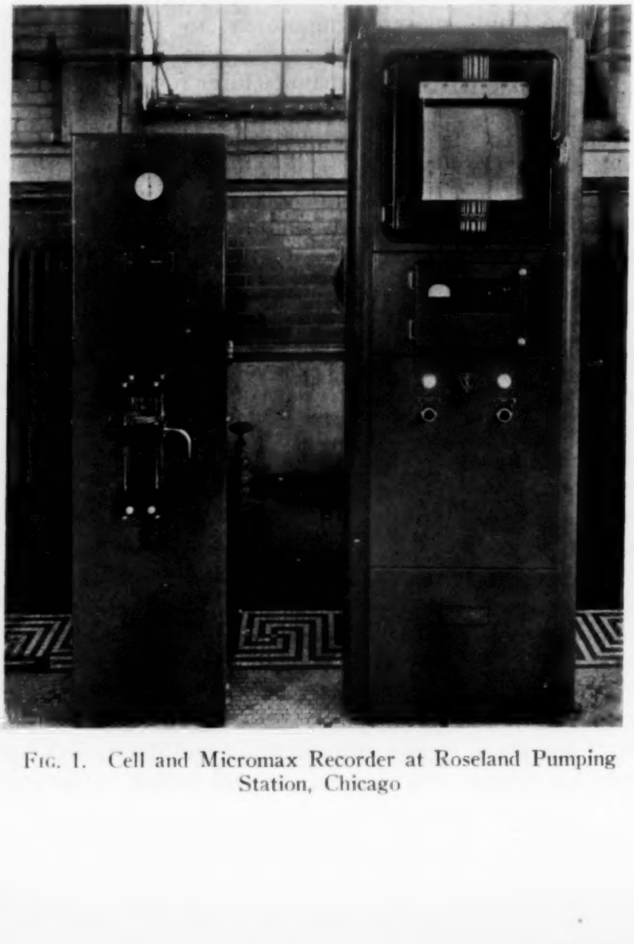

Fig. 1. Cell and Micromax Recorder at Roseland Pumping Station, Chicago

The basal section, which is fastened on a panel board, serves as a support for the cell. This arrangement permits a more rapid inspection of either of the two electrodes than was possible with earlier cell designs, such as the one shown in Fig. 1.

The water in which the residual chlorine is measured enters the cell through an ejector located in the cone-shaped base of the lower compartment of the cell block. A constant rate of flow of the water sampled is maintained through the cell at approximately 1,000 ml. per minute to insure accurate

measurement of the residual chlorine for any given calibration. The flow is maintained by the adjustment of the hydraulic head in the constant level box.

Before starting the flow of water through the cell, about 6 cc. of grit are added to the lower chamber. Jet action of the water passing through the ejector picks up the grit and impinges it against the surfaces of the copper electrode. Continuous bombardment of the grit, a specially prepared alundum product, against the surface of the copper electrode prevents formation of slime growths and corrosion products on the surface of the electrode. These, if allowed to form, would alter greatly the cell reactions involved in the measuring of residual chlorine. The grit is not lost in the process but is recirculated constantly by the water ejector.

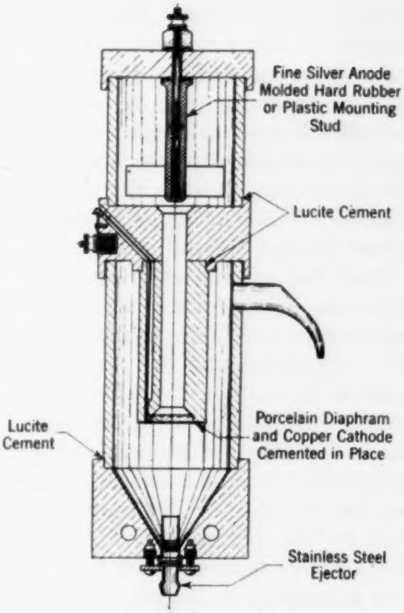

FIG. 2. Lucite Cell

The Recorder

The recording unit is a Model S Micromax, 40,000 series, Leeds and Northrup millivoltmeter equipped with an extra slide wire. The roll chart travels at the rate of 24 in. in 24 hours; a single roll will accommodate approximately two months of continuous recording without changing. The chart is divided into 100 equally spaced divisions. The recorder pen has a large ink reservoir and will function under favorable conditions for at least one month without refilling.

Principle of Operation

A very small constant d-c. voltage is maintained across the cell by a battery circuit. As the molecules of hypochlorous acid in the water come in contact with the copper electrode, they depolarize it, causing thereby a current to flow in the cell circuit which is proportional to the concentration of the hypochlorous acid in the water. These variations in cell current are passed through a resistor, and the resultant voltage drop across the resistor is measured and recorded by the galvanometer.

The control panel of the recorder has three knobs for use in operation and adjustment. One is for setting the voltage applied to the cell. The second adjusts a calibrated slide wire which controls the cell sensitivity, or the number of scale divisions on the recorder per unit concentration of residual chlorine. The third adjusts the bias, and so controls the operating range of any given calibration but does not affect the cell sensitivity.

Methods of Checking and Calibrating Recorders

Daily routine tests are necessary to check the sensitivity of the cell in scale divisions on the recorder per unit con-

centration of residual chlorine. The location of the zero residual chlorine position on the scale is determined by passing unchlorinated water through the cell. If unchlorinated water is not readily available the chlorinated water may be de-chlorinated with a 1 per cent solution of sodium nitrite before being passed through the cell.

Once the residual chlorine value for a specific chart reading has been determined by one of the common laboratory procedures and the zero residual position located on the chart, it is a simple calculation to determine the number of scale divisions which are equivalent to a unit concentration of residual chlorine. The unit in Chicago is 1 lb. per mil.gal. (Only unit divisions are reproduced in Figs. 4–7.)

It is possible by means of the sensitivity control to adjust the cell sensitivity to any value between 1 and 20 chart scale divisions for each pound per mil.gal. of residual chlorine. A cell sensitivity of 10 scale divisions for each pound of residual chlorine per million gallons is most generally used. This gives the recorder a range of 0 to 10 lb. per mil.gal. A cell sensitivity of 20 scale divisions for each pound per mil.gal. would give the recorder a range of 0 to 5 lb. per mil.gal. and likewise a sensitivity of 5 scale divisions for each pound per mil.gal. would give the recorder a residual chlorine range of 0 to 20 lb. per mil.gal.

The bias adjustment permits the shifting of these ranges on the scale chart. Such an arrangement makes it possible to shift within the recorder chart scale almost any range of equal increments of unit concentration of residual chlorine desired. For example, if the cell sensitivity was adjusted to make ten scale divisions equivalent to 1 lb. per mil.gal. a scale range of 0 to 10 lb., 5 to 15 lb., 10 to 20 lb., etc., could be accommodated on the chart by means of the bias control.

Influencing Factors

There are several factors besides residual chlorine which may affect the magnitude of the current flowing through the cell. Most of these factors can be detected by routine checks and can be compensated for by use of the adjustment knobs provided for this purpose. The most important influencing factors are:

1. *Electrode Deterioration:* A gradual loss of cell sensitivity has been traced to chemical deposition on the silver electrode. The rate of loss is shown in Fig. 3. Cleaning the silver by immersion in ammonia and nitric acid restores it to maximum sensitivity. These cleanings at present are made at approximately 3-month intervals. With the new cell the cleaning opera-

FIG. 3. Loss in Recorder Sensitivity Due to Ageing of Silver Electrode

tion is a very simple procedure.

The copper electrodes have given no trouble and in some instances have been in constant use for over 2 years. The replacement of old copper electrodes with new ones has had little or no effect on the cell sensitivity.

2. *Temperature:* Change in water temperature affects the location of a given calibration on the chart of the recorder but does not alter the sensitivity at which the cell operates. As the temperature increases the zero point moves up the scale and as it decreases it moves down the scale again. With routine daily checking of the recorder, the zero point can be controlled by adjusting the bias; therefore, temperature is hardly a limiting factor.

3. *Hydrogen-Ion Concentration:* Changes in the pH of the water have an effect similar to changes in water temperature, but the specific reaction is reversed. As the pH increases the zero point moves downscale and as it decreases the zero moves upscale. On water where pH values are relatively constant, such as that from Lake Michigan, this factor need not be given much consideration.

4. *Combined Chlorine:* It has been established by the manufacturer that cells function with a lower sensitivity when measuring chloramines than when measuring free chlorine. Any given calibration for free residual chlorinated water would be lost, therefore, when changing to a chloramine residual water, and the recorder would have to be recalibrated. It may be that other of the less active combined organic chlorine compounds have a similar effect, and reduce the amount of cell current per unit of residual chlorine in the water.

Figure 4 illustrates the reduction of cell current in the presence of chloramines.

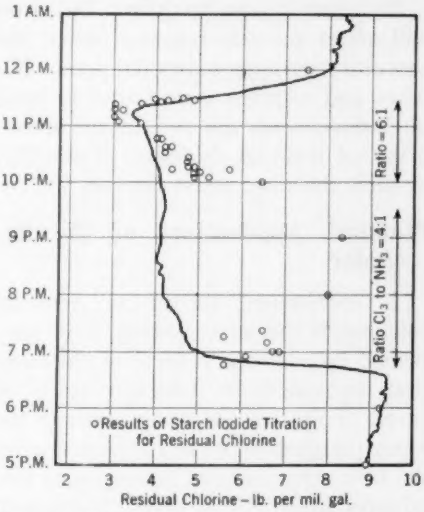

FIG. 4. Reduction of Cell Current in the Presence of Chloramines

The residual produced and recorded when chlorine and ammonia were applied in a 4:1 ratio was much lower than the values found and plotted by titration. The drop in residual chlorine, as determined by laboratory test at about 7 P.M., was caused by the "break-point" effect due to higher ratio of chlorine to ammonia in the outlet water for a short period at the beginning of the ammonia treatment. The residual by test returned nearly to normal between 8 and 9 P.M. The ammonia dosage later was reduced to a 6:1 ratio, at which time tests showed that the residual chlorine dropped considerably.

5. *Miscellaneous Factors:* According to the manufacturer, dissolved salts such as calcium and magnesium within ranges of concentration usually occurring in public water supplies have little effect on the cell. If the concentrations are high enough, it is possible that they will change the conductivity of the water and thus cause a slightly increased cell current.

Manganese has no effect but iron will affect the cell response when the concentration approaches 3.0 ppm. Nitrites and nitrates were found to have no influence on the cell in the measuring of residual chlorine. Turbidity, as such, does not affect the cell.

Practical Applications of the Recorder

A continuous record of residual chlorine in the water supply is of particular value in the control of chlorination treatment in Chicago since at seven of the ten pumping stations the water pumped from the stations reaches the first consumers in from one to two minutes after it has been chlorinated. Routine ortho-tolidine tests for residual chlorine are made at these pumping stations at intervals of one hour and at times of emergency at one-half-hour intervals. Much could happen to the chlorination of the water during the intervals between tests. At a station pumping at the rate of 120 mgd., 5 mil. gal. of water may be discharged into the distribution system between the routine hourly tests for residual chlorine. In full realization of this weakness in the chlorination control system, the division was on the lookout for a reliable continuous chlorine recorder and was glad to take advantage of the offer made by Wallace & Tiernan to install a recorder for test purposes.

That this concern was justified is indicated by Fig. 5, which shows how an interruption of chlorine in the mixing basin was detected on the residual chlorine chart by a drop to zero. The recorder gave immediate notice of the chlorination failure to the chemical control engineer, and the trouble was traced to a temporary failure of the auxiliary water supply to the chlorinators. In six minutes the interruption was cleared, and the routine laboratory tests, taken at half-hour intervals, failed to show any interruption of chlorination. Figure 5 also shows a routine calibration for zero, as mentioned previously.

Again, variations in the chlorine absorptive properties of the raw water produced marked fluctuations in the residual chlorine record of the plant effluent. The recorder showed a pronounced decrease in residual chlorine between 1 and 3:30 A.M., which warned the chemical control engineer of the need for postchlorination (Fig. 6). Following the establishment of a safe operating chlorine residual, postchlorination was stopped at 6:30 A.M. Almost at the same moment the recorder showed another marked drop in residual chlorine, necessitating immediate restoration of

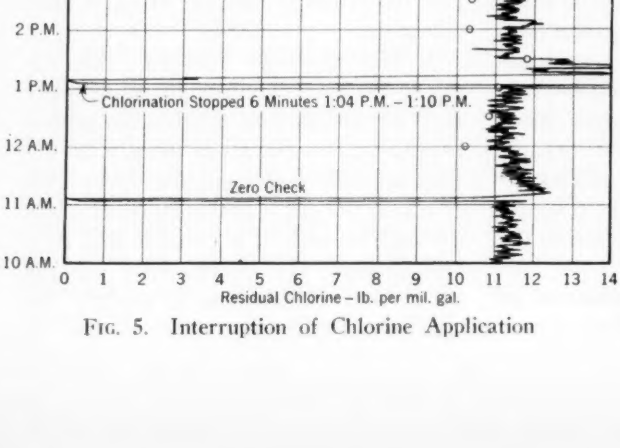

Fig. 5. Interruption of Chlorine Application

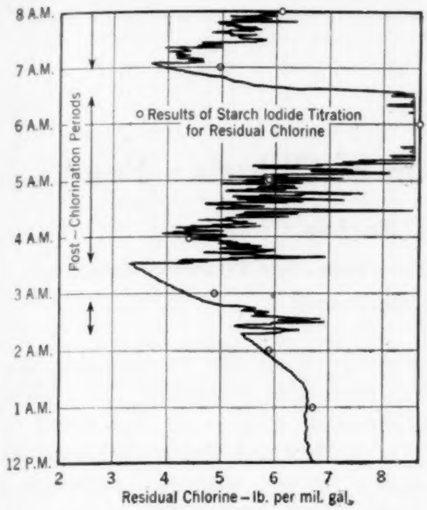

FIG. 6. Varying Chlorine Absorptive Properties of Raw Water

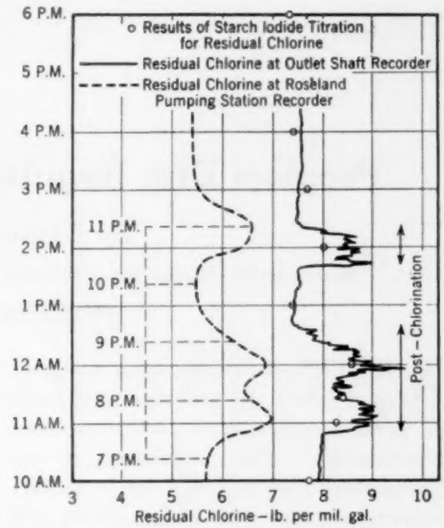

FIG. 7. Comparison of Residual Chlorine in Water Before and After Eight Hours in Tunnel System

post-chlorination. Water with an extremely low residual would have been leaving the plant for nearly an hour in each instance before detection by routine laboratory methods, had the chemical control engineer been dependent upon hourly residual chlorine tests.

Post-chlorination is also illustrated in Fig. 7, which is the record of the South District Filtration Plant effluent. Plotted alongside it is the residual chlorine record of the same water when it reached the Roseland Pumping Station through the tunnel system approximately eight hours later. The effect of two periods of post-chlorination on the residual chlorine of the plant effluent is shown by the recorder, and the same trends are apparent on the Roseland record. The chlorine demand of the water, caused by the absorption of chlorine in the tunnel, is clearly demonstrated by the difference in the two residual records.

Conclusion

The continuous recording of chlorine residuals has proven its worth in a variety of ways. The instrument is convenient to use and adaptable to a variety of needs. The design of the cell now used has been considerably improved over the original unit under test, and the manufacturer is still carrying on work to improve its accuracy and general applicability for residual chlorine measurement and recording.

The Leeds and Northrup Micromax Recorder has been a practical instrument for measuring and recording voltage changes in electrolytic cells for a number of years and has given little trouble in operation.

Program Disc Regulation of Chlorine Feed

By Edwin W. Barbee

Water Purif. Engr., San Francisco Water Dept., San Francisco, Calif.

A contribution to the Journal

A SIMPLE device has been designed to regulate the chlorine feed rates of certain types of injector-operated chlorinators. This regulation is accomplished mechanically by a motor-driven program disc which raises and lowers the level of the make-up water to the injector. The size of the orifice installed in the chlorinator and the designed disc setting, which varies with the time of day, then determine the chlorine feed rate.

This device can be used where the flow and chlorine demand of the water are reasonably regular and can be anticipated. A study of past flow records and known conditions governing present flows will reveal whether the flow cycle is repetitive from day to day. After determining the hourly flows and the chlorine demand of the water to be treated, a program disc can be laid out which will operate the chlorinator to anticipate the varying feed rates. Discs can be changed quickly to meet seasonal or other changes.

Experience With a Distribution Reservoir

The need for such a variable-feed chlorinator was first felt by the San Francisco Water Department at the College Hill Reservoir in 1940. The chlorinated water entering this open reservoir from the transmission line was acceptable bacterially, but a slight contamination, possibly introduced by airborne dust and birds, was sometimes present in the effluent. Although a Wallace and Tiernan type MSV A-161 manually controlled chlorinator had been installed on the outlet for some time, taste and odor complaints were quite numerous.

To attack the problem, a study was first made of past flow records, and the cyclic flow patterns observed. Figure 1 shows the average weekly flow by hours. An average 24-hour flow is shown in Fig. 2, which also shows maximum and minimum rates of flow for each hour of the day. A chlorine dosage program based on this average curve would approach ideal dosage.

According to the flow rates shown in Fig. 2, if a constant chlorine dosage of 3 lb. per mil.gal., predicated on the average flow, is used, a maximum overdosage can occur at 8:00 A.M. resulting in a treatment of 6.4 lb. per mil.gal. A maximum underdosage of 2.3 lb. per mil.gal. is also possible at this hour. These maximum and minimum flows are taken from the flow records of several years and represent extreme conditions. Ordinarily, the variation in flow causes a fluctuation in treatment between 2.5 and 5.7 lb. per mil.gal.

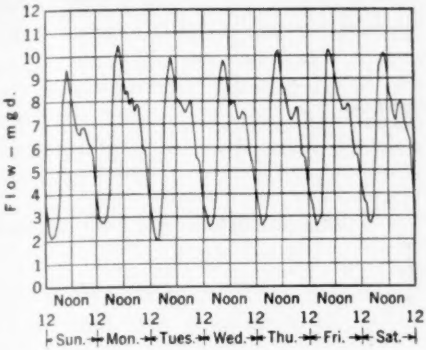

Fig. 1. Weekly Average Flow From College Hill Reservoir

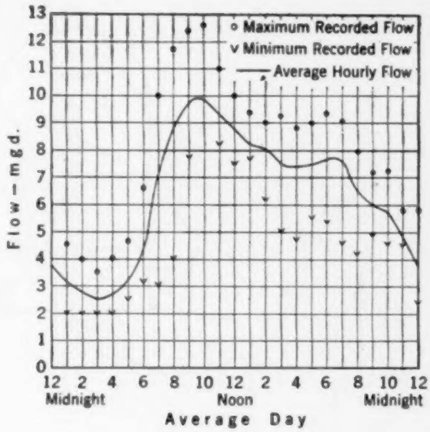

Fig. 2. Variations in Flow From College Hill Reservoir

Design of Program Controller

The use of fully automatic equipment was at first considered for this station, but instead it was decided to use the existing chlorinator and modify it for program operation. Figure 3 shows the principles of operation employed. A 4-w. synchronous electric clock motor drives the program disc through a set of reduction gears. A runner with a roller bearing that fits along the edge of the program disc travels up and down vertical guide rods. Attached to the runner is a flexible wire which is carried over pulleys to the suction cup. The make-up water lines to this cup are of thin wall rubber tubing which permits the required amount of vertical play. Rotation of the program disc then raises or lowers the suction water cup, the water level of which, relative to the center line of the injector, determines the inches of water vacuum across the orifice meter. This vacuum causes the water level in the meter to rise; the rate of chlorine flow in pounds per 24 hours can then be read.

The operation of the disc in three different positions is shown in Fig. 3. When the bearing is at A, the suction cup is as shown, causing vacuum H_a.

TABLE 1

Vacuum Heads Necessary to Produce Required Chlorine Dosages Using a 40-lb.-per-day Orifice

Hour	Flow Rate, *mgd.*	Chlorine Feed, *lb. per day*	Negative Head, *in. of water*
12 Midnight	3.8	11.4	0.62
1 A.M.	3.1	7.3	0.41
2	2.8	8.4	0.33
3	2.5	7.5	0.26
4	2.6	7.8	0.29
5	3.1	9.3	0.41
6	4.2	12.6	0.73
7	7.2	21.6	2.20
8	8.8	26.4	3.30
9	9.8	29.4	4.10
10	9.9	29.7	4.10
11	9.4	28.2	3.70
12 Noon	8.7	26.1	3.20
1 P.M.	8.2	24.6	2.80
2	8.1	24.3	2.80
3	7.5	22.5	2.40
4	7.4	22.2	2.30
5	7.5	22.5	2.40
6	7.7	23.1	2.50
7	7.6	22.8	2.40
8	6.4	17.2	1.70
9	5.9	17.7	1.50
10	5.7	17.1	1.40
11	4.8	14.4	1.00

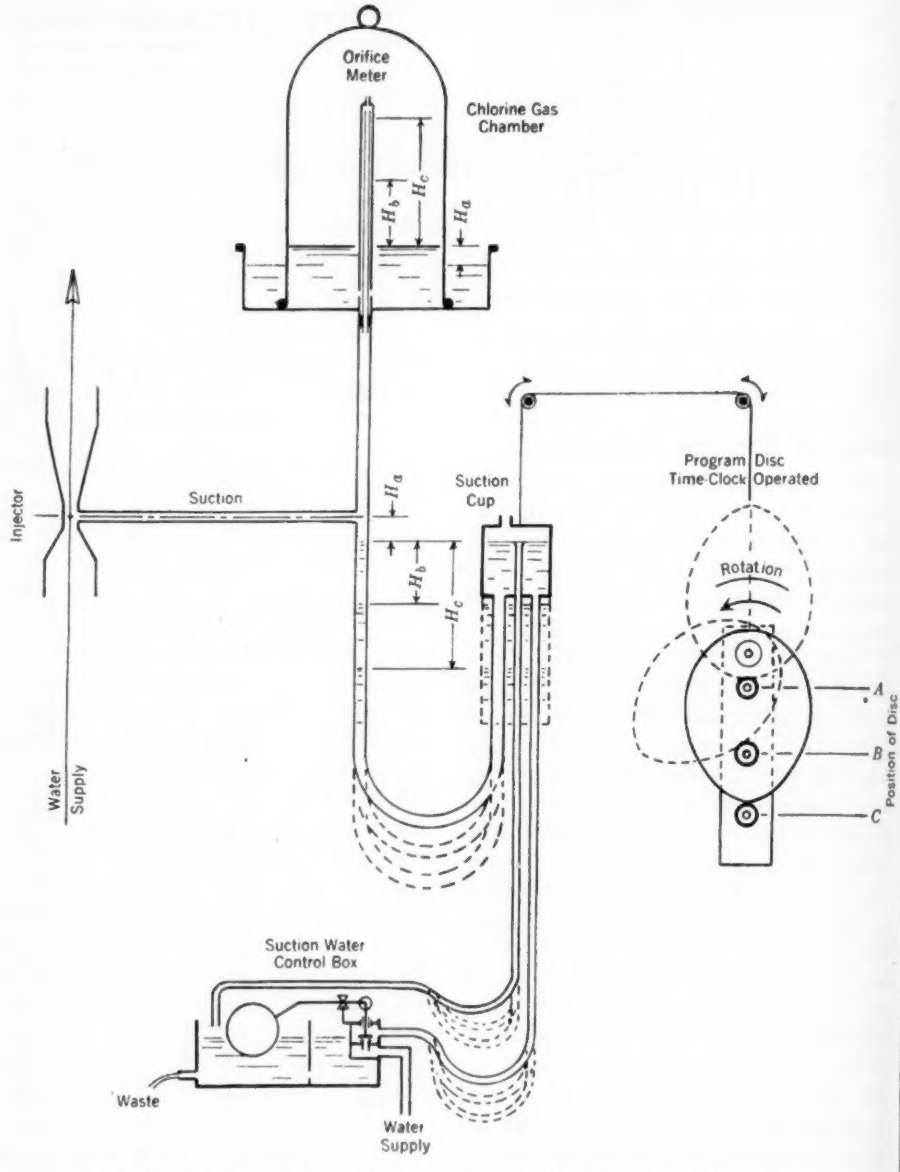

FIG. 3. Functional Drawing of Chlorinator Operating With Regulator

This is the normal vacuum under the bell jar and the zero of the orifice meter. As the disc revolves counterclockwise, the suction cup falls and the vacuum increases until position C is attained. The head across the orifice at this point is H_c. Continued rotation of the disc gives, at any intermediate point B, the resultant head H_b. The quantity of the make-up water is

not constant but varies inversely with the amount of chlorine metered through the orifice. The suction water control box automatically takes care of the make-up water for the injector by maintaining a constant small overflow to waste.

Laying Out the Program Disc

Once the values of the average hourly flow rates were known, it was determined that a chlorine dosage of

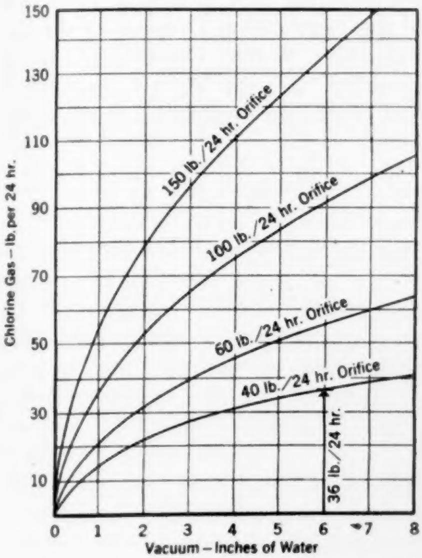

Fig. 4. Calibration Curves for Chlorine Gas Meters

3 lb. per mil.gal., or 0.36 ppm., would satisfy the demand and give the required residual. Table 1 summarizes the rates of flow and the dosages, and the vacuum heads necessary to produce them. In Fig. 4, the calibration curves for four orifices are plotted. At 6 in. of vacuum head, the 60-lb.-per-day orifice delivers 55 lb. a day; the 40-lb. orifice, which it was decided to use, meters 36 lb. The effect of changing orifices with the same program

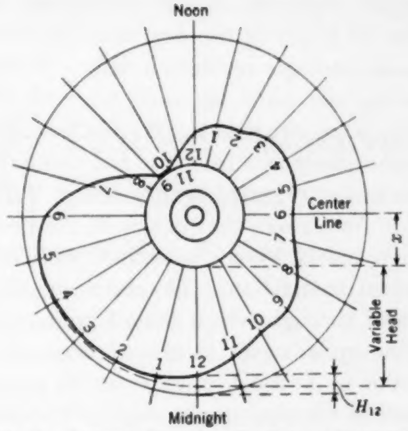

Fig. 5. Layout Showing Design of Program Disc

disc is apparent from these curves.

With the required vacuum head known for the different hours of the day, the disc was laid out (Fig. 5). A circle was drawn and divided into 24

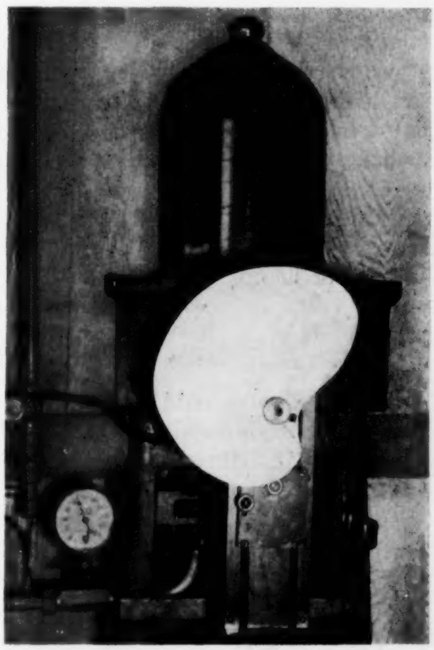

Fig. 6. Photograph of Control Mechanism

equal segments which correspond to the 24 hours of the day, since the disc makes a single revolution daily. Points along the radii for each hour of the day were obtained by plotting from the outer circle as a base line and using the values of negative head given in Table 1. As shown, the disc is in the position for 12 o'clock midnight, with H_{12} equal to 0.62 in. The total negative head through which the 24-hour chlorine cycle varies is also shown. The value of X, the distance from the center line of the shaft to the edge of the disc, should be sufficient for shaft and hub clearance. Figure 6 is a photograph of the equipment.

Performance

The unit, which has been in operation for over four years, has resulted in the reduction of customer complaints. Routine bacterial tests made twice weekly indicate the satisfactory operation of the equipment. Maintenance has been nominal and consisted of cleaning of strainers, resetting of the disc after current interruptions and oiling the moving parts. Several times the disc was changed to meet the changing flow demands. The staff of the Purification Division of the San Francisco Water Department is responsible for the design, installation and satisfactory operation of the equipment.

The Inactivation of Partially Purified Poliomyelitis Virus in Water by Chlorination

By Serge G. Lensen, Morris Rhian and Max R. Stebbins

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Presented at the Michigan Section Meeting, Traverse City, Mich., Sept. 19, 1946

THE possibility that poliomyelitis might be a water-borne disease has stimulated a number of investigators (1–7) to study the effect of chlorine, in amounts comparable to those commonly used in water purification, on the poliomyelitis virus. The work of these authors was done with crude suspensions of infected tissue in water, and the residual chlorine values reported have been expressed only in terms of total chlorine or chloramine. In these studies, a limited number of monkeys was employed to determine the activity of the virus.

The authors report here the results of their own preliminary work on inactivation by chlorination of poliomyelitis virus in partially purified suspensions, using a mouse-adapted strain of virus to permit the use of adequate numbers of experimental animals. In view of the admittedly greater bactericidal action of free chlorine as compared with chloramine (8, 9) it seemed possible there might be the same difference in virucidal action. The differentiation between free chlorine and chloramine is essential for the evaluation of free residual chlorination, which can be defined as the addition of chlorine in sufficient quantities to produce and maintain free available chlorine residuals to the exclusion or near exclusion of chloramine residuals. Therefore, in all the authors' work, the residual was determined as free chlorine and chloramine.

Material and Technics

Source of Virus

Armstrong's mouse-adapted Lansing strain of poliomyelitis virus was used in all experiments. Spinal cords and medullae of paralyzed mice were ground (either in a mortar with sterile alundum or in a Waring Blendor) to a 10 per cent suspension in saline. Physiological saline (0.87 per cent NaCl) containing 0.0047 molar NaH_2PO_4 and 0.0162 molar Na_2HPO_4, pH 7.3 ± 0.1, was used for all virus suspensions.

Purification of Virus

Immediately after grinding, all samples of this suspension were centrifuged in a horizontal centrifuge at 1,900–2,000 rpm. for 25 minutes, and the supernatant was used as the primary virus suspension. This was frozen, kept overnight at from $-55°$ to $-60°$ C. and thawed just before being used for further treatment. The suspension was treated by differential centrifuga-

TABLE 1

Date	Virus Preparation	Chlorine Applied, *ppm.*	Residual Chlorine After 10 Minutes, *ppm.*		Residual Chlorine After ½ Hour, *ppm.*		Residual Chlorine After 1 Hour, *ppm.*	
			Free Cl_2	Chloramine	Free Cl_2	Chloramine	Free Cl_2	Chloramine
								Experiment With
10–15–45	Supernatant after 20,000 rpm. for 15 minutes	18 20 22	0 0 0	0.5 1.0 2.0	0 0 0	0.35 0.5 1.0	0 0 0	0 0 0
								Experiments With
11–5–45	1 cycle†	6 7 7.5	0.5 1.0 1.4	0.5 1.0 0.6	0.15 0.75 0.75	0.35 0.65 0.65	0.1 0.45 0.35	0.25 0.55 0.40
11–13–45	1 cycle	8.1 8.2	2.0 – 2.0 +	0 0	1.0 1.2	0.1–0.2 0.2	0.35 0.35	0.15 0.15
1–7–46‡	1 cycle	4 1.5	0.05 0	0.70 0.5 +	0 0	0.75 – 0.5 +	0 0	0.75 – 0.5 +
1–16–46‡	1 cycle	3 4.5	0 0.15	0.3 – 0.1	0 0	0.10–0.15 0.1	0 0	0.10–0.15 0.1
2–21–46‡	1 cycle	3.0 2.0	0 0	0.75 0.5	0 0	0.75 0.5	0 0	0.5 0.5
3–1–46‡	1 cycle	1.0 1.5 2.0	0 0 0	0.15–0.20 0.4 0.75 –	0 0 0	0.15–0.20 0.4 – 0.5	0 0 0	0.15–0.20 0.3 –0.4 0.5
3–8–46‡	1 cycle	2.0 2.0§ 9.0 9.0§	0 0 0.5 0.5	0.5 – 0.5 – 0.5 0.5	0 0 0.15 0.15	0.4 0.4 0.35 0.35	0 0 0.05 0.05	0.3–0.4 0.3–0.4 0.35 0.35
1–2–46	2 cycles	1.5 3	0.1 1.0	0.1 + traces	traces 0.75	0.1 + traces	0 0.5	0.1 0.2–0.25
12–27–45	3 cycles	2.25	0.75	0.10–0.15	0.5	0.15	0.5	0.15
								Experiments With
12–10–45	1 cycle	5.1 2	1.4 0	traces 0.75 –	1.4 0	traces 0.35	1.4 – 0	traces 0.15
12–11–45	1 cycle	1 1.3	0.2 0.3	0.2 0.1	0.15 + 0.15 +	0 0.05	0.1 + 0.1	0 0.05
12–18–45	3 cycles	2 1.5 1.2	1.0 0.5 – 0.35 –	traces traces traces	1.0 – 0.35 + 0.35 –	traces traces traces	0.75 – 0.2 + 0.2	traces traces traces

* Ratio of paralyzed mice to total number of mice (paralyzed plus survivors).
† Cycle of purification by fractional centrifugation.
‡ 0.1 ppm. of ammonia hydroxide added to the distilled water.

TABLE 1—*Continued*

Residual Chlorine After 2 Hours, *ppm.*		Outcome * of Mouse Experiment Injected After:			Controls:		LD₅₀, %
Free Cl_2	Chloramine	½ Hour	1 Hour	2 Hours	Distilled Water	Saline	
1% Virus							
0 0 0	0 0 0	16/18 18/20 18/20	17/18 19/20 18/20	18/19 18/19 16/17	16/18	17/17	0.048
0.5% Purified Virus							
0.05 0.1 0.1	0.25 0.25 0.3	1/20 1/20 3/18	4/19 0/20 2/20	2/19 0/20 0/16	16/19	20/20	0.0097
0.15 0.15	0.15 0.10	0/18 0/20	0/16 0/19	0/19 0/20	19/19	20/20	0.031
0 0	0.75 – 0.5 +	1/20 10/17	0/20 11/19	1/19 10/19	19/19	19/20	0.024
0 0	0.15 – 0.1	0/19 0/19	0/20 0/19	0/20 0/19	19/20	15/20	0.02
0 0	0.5 0.5	0/18 4/17	0/18 5/18	0/18 1/17	13/15	18/19	0.029
0 0 0	0.15 0.3 – 0.5 –	14/20 9/14 10/20	17/19 8/20 2/18	11/17 4/18 4/19	17/18	17/20	0.216
		12/17 8/18 0/16 0/17	8/17 10/16 0/17 0/16		18/18 18/18§	18/20	0.037
0 0.35 –	0.05 0.5–0.1	0/19 0/18	0/20 0/19	0/20 0/20	18/19	15/20	0.097
0.35	0.15	0/20	0/20	0/19	13/20	7/20	0.43
0.25% Purified Virus							
0.5 0	0 0	0/20 0/19	0/20 0/20	0/19 0/20	9/20	13/20	0.069
0 0.05	0 0.05	0/20 0/19	0/17 0/17	0/20 0/20	15/20	10/20	‖
0.75 – 0.2 – 0.15 +	traces traces 0	0/20 0/20 0/15	0/19 0/20 0/19	0/20 0/20 0/19	5/19	9/20	0.65

§ 1 drop of a 10 per cent suspension of normal mouse brains and spinal cords added to 2 ml. of sample just before injection.

‖ Same virus preparation used as for experiment of 12–10–45.

tion in a Beam's type (10) ultracentrifuge, and each time the primary suspension was clarified by centrifugation at 20,000 rpm. (approximately 29,000 gravities) for 15 minutes and the sediment discarded. The supernatant was used for the next centrifugation at 40,000 rpm. (approximately 117,000 gravities) for 3 hours (in a Masket-type rotor with the tubes at a 10-deg. angle). The supernatant from this centrifugation was discarded and the pellets washed quickly with $\frac{1}{2}$–1 ml. saline without mixing. The pellets were then resuspended in saline by mixing with a pipette, using 2 ml. per tube and pooling the suspensions in a 100-ml. centrifuge bottle. The tubes were thoroughly washed with another set of 2-ml. portions of saline, and the washings were added to the pooled suspensions. Finally the volume was restored to the original amount and the suspension mixed vigorously in a mechanical shaker for 10 minutes. The particulate matter was thrown out in an angle centrifuge at 4,000 rpm. (approximately 3,200 gravities) for 15 minutes. The sedimentation of the virus at 40,000 rpm. and resuspension of the pellet followed by clearing of the suspension at 4,000 rpm. are considered as a cycle of ultracentrifugation. For the virus suspensions that were further purified, this cycle was repeated once or twice. The purified suspensions were frozen and stored at from $-55°$ to $-60°C$. until used, usually two or three days later.

Chlorination Procedure

All of the experiments were carried out with double-distilled ammonia-free water. The water was sterilized by boiling for a few minutes the day before the experiment. Chlorine water, prepared by passing chlorine gas from a generator through distilled water, was used for chlorination. In the experiments of Jan. 7 and 16, 1946 (Table 1), approximately 0.1 ppm. of ammonium hydroxide was added to the water. The ortho-tolidine arsenite test (Hallinan) (11), as described by Griffin (12), was used for determination of residual chlorine, to allow differentiation between free chlorine and chloramine.

The pH of the chlorinated water samples ranged from 7.0 to 7.4, and the temperature varied from 21° to 25°C. Nitrogen was determined by a modified micro-Kjeldahl method.

It proved to be impossible to predict the composition or amount of the residual chlorine on the basis of the amount of virus suspension and chlorine applied. Therefore, trial mixes of the desired percentage of virus suspension and varying amounts of applied chlorine were prepared. On the basis of the residual after 10 minutes of contact, conditions were selected for the day's experiments. The character of the residual after 10 minutes of contact has therefore been selected as a basis for identifying the various mixtures studied.

The experiments were carried out as follows: The amounts of 10 per cent virus suspension—that is, the dilution of the original infected tissue suspension, assuming no loss of virus during purification—that were necessary to obtain the desired concentration were added to 100-ml. portions of water. After thorough mixing, different amounts of chlorine were applied to test portions and the residual (free chlorine and chloramine) determined after 10 minutes of contact. Samples which gave desired values of residual chlorine were chosen for further study. The residual chlorine was determined

TABLE 2

Nitrogen Content of Partially Purified 10 Per Cent Virus Suspensions

Treatment	*Number of Samples*	*Nitrogen, mg./ml.* Range	*Nitrogen, mg./ml.* Average
Cleared at 2,000 rpm.	3	0.935–1.55	1.195
Clarified at 20,000 rpm.	3	0.74–1.01	0.837
1 Cycle of Ultracentrifugation	5	0.026–0.058	0.041
2 Cycles of Ultracentrifugation	1	0.017	0.017
3 Cycles of Ultracentrifugation	1	0.001	0.001

after contact periods of 30 minutes, 1 and 2 hours. Twenty mice were inoculated for each contact period for each sample simultaneously with the determination of the residual.

Animal Control Studies

The following controls were included in each experiment: Twenty mice were injected with water containing the same amount of virus as the chlorinated samples, and 20 mice were inoculated with the same concentration of virus suspension in saline. The 10 per cent virus suspension was exposed to the same room conditions as the experimental samples. Dilutions for the controls were made from this stock suspension, and the control animals were injected after the animals receiving the chlorinated samples were inoculated. A titration of the virus on the basis of ten 2-fold dilutions was also included in each experiment except that of Dec. 11, 1945. The LD_{50} titer (50 per cent end-point) of the virus suspension was calculated by the method of Reed and Muench (13). This allowed a comparison of the potencies of the various virus preparations used.

Evaluation of Virus Activity

White Swiss mice, three to five weeks old, were inoculated intracerebrally with 0.03 ml. The observation period after inoculation was 30 days, and the mice were checked daily. Deaths within the first 24 hours after inoculation were considered accidental. Spinal cords and medullae of mice dying without symptoms later than 24 hours after infection were passed into other mice for detection of virus. If the passage was negative, the death was considered accidental, and the mouse was not included in the evaluation of results.

Dechlorination Investigations

The suspensions were not de-chlorinated before injection, on the assumption that the residual chlorine is immediately used up by contact with brain tissue and therefore there is no further action of chlorine upon the virus. This was confirmed by preliminary ***in vitro*** tests, in which one drop of a crude 10 per cent suspension of normal mouse brains and spinal cords (supernatant after centrifugation at 2,000 rpm. for 25 minutes) instantly de-chlorinated 2 ml. of the samples. Also, as can be seen in Table 1, in the experiment of Mar. 8, 1946, two portions of each sample were injected into mice, one not de-chlorinated and the other de-chlorinated by addition of a crude suspension of normal brains and spinal cords just before the injection. There was no difference in the outcome of the experiment.

Experimental

A few preliminary experiments made it obvious that the supernatant after centrifugation of the original 10 per

cent suspension for 25 minutes at 1,900 to 2,000 rpm. could not be used for the purpose of the investigation. Even the completely clear (but colored) supernatant obtained after subsequent centrifugation at 20,000 rpm. for 15 minutes contained far too much organic matter. This is shown in Table 1 in the experiment of Oct. 15, 1945, in which such a supernatant in a dilution corresponding to 1 per cent of the original tissue suspension was used. The authors applied 18, 20 and 22 ppm. of chlorine, and the residual after 10 minutes of contact was determined as 0.5 ppm., 1.0 ppm. and 2.0 ppm., respectively, of chloramine. There was no free available chlorine. No inactivation of the virus was noticed up to two hours of contact, and there probably would not have been inactivation after a longer period of contact as there was no residual after one hour. The authors tried then to achieve free residual chlorination, but did not succeed in obtaining a chloramine-free residual after applying as much as 120 ppm. of chlorine.

In order to reduce the amount of extraneous organic matter, the authors began to use partially purified virus suspensions for further work. The results of nitrogen determination, summarized in Table 2, give an indication of the degree of purification of a 10 per cent suspension of infected tissue effected by one or more cycles of centrifugation. The calculated nitrogen content of the samples used in chlorination experiments is comparable to that of samples of five natural waters, as shown in Table 3.

The authors also reduced the amount of organic matter in the chlorinated samples by further dilution of the virus suspension. However, the lowest concentration they were able to use without going beyond the range of infectivity of the virus suspension was 0.25 per cent.

TABLE 3

*Nitrogen Content of Natural Waters and Virus Suspensions Used for Chlorination Experiments**

	Nitrogen, mg./ml.
Red Cedar River, East Lansing, Mich.	0.00132
Well Water, Michigan Dept. of Health	0.00021
City Water, Lansing, Mich.	0.00036
Well Water, Rockford, Ill.	0.00090
Jones Lake, Lansing, Mich.	0.00259
0.5% Virus Suspension After 1 Cycle of Ultracentrifugation (avg.)	0.00205
0.25% Virus Suspension After 1 Cycle of Ultracentrifugation (avg.)	0.00102
0.5% Virus Suspension After 2 Cycles of Ultracentrifugation	0.00085
0.25% Virus Suspension After 2 Cycles of Ultracentrifugation	0.00042

* Calculated from average values given in Table 2.

Chlorination of 0.5 Per Cent Suspensions

The experiments of Nov. 5 and 13, 1945 were carried out with 0.5 per cent virus suspension purified by 1 ultracentrifugation cycle. As shown in Table 1, there was definite inactivation of the virus in the experiment of Nov. 5, 1945. It was still possible, however, to detect a small amount of virus, even after a 2-hour period of contact, in the sample with a residual of 0.5 ppm. free chlorine and 0.5 ppm. chloramine; after ½ hour contact in the sample with a residual of 1.0 ppm. free chlorine and 1.0 ppm. chloramine; and after 1 hour in the sample with 1.4 ppm. free chlorine and 0.6 ppm. chloramine. In the next experiment (Nov. 13, 1945), with a residual after 10 minutes' contact of

slightly under 2.0 ppm. free chlorine in one sample and slightly over 2.0 ppm. in the other, and no chloramine in either, no active virus was detected after 30 minutes, whereas all the control mice became paralyzed.

The experiments of Jan. 7 and 16, Feb. 21 and March 1 and 8, 1946, were carried out in a similar manner (0.5 per cent virus suspension purified by 1 cycle of ultra-centrifugation), but approximately 0.1 ppm. ammonium hydroxide was added to the water. As can be seen in Table 1, there was complete or almost complete inactivation of the virus in less than 30 minutes in the samples containing, after 10 minutes contact, both free chlorine and chloramine in the residual. The composition of the residual was as follows: 0.05 ppm. free chlorine and 0.70 ppm. chloramine in the experiment of Jan. 7, 0.15 ppm. free chlorine and 0.1 ppm. chloramine in the experiment of Jan. 16, and 0.5 ppm. free chlorine and 0.5 ppm. chloramine in the experiment of Mar. 8, 1946.

The residuals of the other samples in these five experiments contained, after 10 minutes contact, only chloramine. In one sample of the experiment of Jan. 16, 1946, with a residual of slightly less than 0.3 ppm. chloramine, and in one sample of the experiment of Feb. 21, 1946, with a residual of 0.75 ppm. chloramine, there was no detectable virus after 30 minutes. In all the other samples with residuals ranging from 0.15–0.20 ppm. to slightly less than 0.75 ppm. chloramine, with no free chlorine, there were different degrees of only partial inactivation of the virus. For instance, in the experiment of Jan. 7, 1946, there was enough active virus, even after 2 hours' contact with chlorine, to infect over 50 per cent of the mice injected. There was slightly more than 0.5 ppm. residual chloramine in this sample after 10 minutes of contact. Approximately the same result was obtained in the experiment of Mar. 6, 1946, with a chloramine residual of slightly less than 0.5 ppm. and in a sample of the experiment of Mar. 1, 1946, with a chloramine residual of 0.4 ppm. A residual of slightly less than 0.75 ppm. chloramine in the experiment of Mar. 1, 1946, also resulted in partial inactivation of the virus.

On the other hand, there was a higher degree of inactivation of the virus in the experiments of Feb. 21, 1946, in a sample with 0.5 ppm. residual chloramine. After 30 minutes of contact with chlorine, there was enough virus left to infect 4 mice out of 17; after 1 hour of contact, 5 mice out of 18; and after 2 hours of contact, only 1 mouse out of 17. In contrast to this, there was no significant inactivation of the virus in a sample of the experiment of Mar. 1, 1946, with 0.15–0.20 ppm. residual chloramine. The LD_{50} titers of the suspensions used for these experiments were: 0.024, 0.02, 0.029, 0.216 and 0.03 per cent, respectively.

For the experiment of Jan. 2, 1946, 0.5 per cent of virus suspension purified by 2 cycles of ultracentrifugation was used. The residual after 10 minutes of contact contained 0.1 ppm. free chlorine and slightly over 0.1 ppm. chloramine in one sample and 1.0 ppm. free chlorine and traces of chloramine in the other. None of the mice injected with the chlorinated samples became paralyzed, although the controls show that there originally was enough virus to bring down most of the mice. The titer of this virus suspension ($LD_{50} = 0.097$ per cent) was comparable to the titer of preparations purified by one cycle of ultracentrifugation.

The experiment of Dec. 27, 1945, was carried out with 0.5 per cent of virus suspension purified by three cycles of ultracentrifugation. The residual after 10 minutes of contact contained 0.75 ppm. free chlorine and 0.1–0.15 ppm. chloramine. There was no detectable virus after ½ hour of contact, whereas more than 50 per cent of the control mice injected with 0.5 per cent of the virus suspension in untreated water became paralyzed. The titer of this virus preparation (LD_{50} = 0.43 per cent) was lower than that of preparations purified by one or two cycles of centrifugation.

Chlorination of 0.25 Per Cent Suspensions

A virus preparation purified by one cycle of ultracentrifugation was used for the experiments of Dec. 10 and 11, 1945. The residual in the various samples after 10 minutes of contact was composed of: 1.4 ppm. free chlorine and traces of chloramine; no free chlorine and slightly under 0.75 ppm. chloramine; 0.2 ppm. free chlorine and 0.2 ppm. chloramine; and 0.3 ppm. free chlorine and 0.1 ppm. chloramine, respectively. There was no detectable active virus after ½ hour in any of the samples, although the control mice became paralyzed in significant numbers in both experiments (9 out of 20 and 14 out of 20, respectively). The LD_{50} of the purified virus suspension used for these experiments was 0.069 per cent.

The authors also carried out one experiment with 0.25 per cent of virus suspension purified by three cycles of ultracentrifugation. The residuals after 10 minutes of contact in the three samples used (Dec. 18, 1945) consisted of: 1.0 ppm. free chlorine and traces of chloramine; slightly under 0.5 ppm. free chlorine and traces of chloramine; and slightly under 0.35 ppm free chlorine and traces of chloramine respectively. No active virus was detected in any of the chlorinated samples. The titer of this virus preparation was very low (LD_{50} = 0.65 per cent) and only 5 out of 19 control mice became paralyzed or were shown by passage to other mice to contain virus. Nevertheless the results of this experiment are satistically significant, the Chi Square for the different samples being between 4.63 and 6.04.

Summary and Conclusions

Inactivation of poliomyelitis virus in water by chlorination has been studied by preparing samples of distilled water containing virus suspensions partially purified by differential centrifugation. The pH of the samples varied from 7.0 to 7.4, and the temperature varied from 21° to 25°C. A distilled water solution of chlorine was added, and the type of residual after 10 minutes of contact was used to characterize the sample.

In samples with residuals consisting essentially of free chlorine (with very little or no chloramine), no active virus was detected after ½ hour of contact. In samples with residuals consisting of mixtures of free chlorine and chloramine, there was either complete or nearly complete inactivation of the virus. Results with samples in which the residual consisted only of chloramine were not consistent.

In samples of 0.25 per cent virus suspension containing residuals as low as 0.2 ppm. free chlorine plus 0.2 ppm. chloramine; 0.3 ppm. free chlorine plus 0.1 ppm. chloramine; and slightly less than 0.35 ppm. free chlorine plus traces of chloramine, the virus was inactivated in less than ½ hour. In one ex-

periment, 0.5 per cent virus suspension was not completely inactivated in the presence of higher residual chlorine values.

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The Performance of Sedimentation Basins

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Presented on May 9, 1946, at the Annual Conference, St. Louis, Mo.

IN recent years considerable interest has attended the design details of sedimentation units, and there has been a definite evolution in the type and size of sedimentation tanks employed in both water and sewage works installations. Today considerably more interest is aroused by the requirement for cheap industrial waste treatment units, which necessarily must be extremely efficient in order to cut down construction costs.

A good example of such a tank is the standardized design of gravimetric separation units specified by the American Petroleum Institute, which conducted considerable research on the subject to arrive at the most economical unit that would perform the service required. As a result of its work, the A.P.I. developed a unit which required a retention period of something like 12 to 13 minutes for the gravimetric separation of flocculent materials. This may be contrasted with the 2½-hour detention periods commonly applied in sewage treatment works and the 8- and 12-hour detention periods commonly applied in water treatment plants.

The A.P.I. laid great stress on inlet cross-sectional distribution and velocity suppression in order to obtain uniform cross-sectional displacement, together with baffles designed to prevent tendencies.

History of Basin Design

Generally speaking, water works were the first utilities to be given serious attention by consultant engineers, and an important feature of any water works was the prodigious sedimentation chamber. Years later, sewage treatment works came to the fore, and consultant engineers were faced with the problem of justifying costs of structures that were not to produce any useful product or revenue. Consequently, attention was given to the design of relatively smaller sedimentation units which presumably would produce the same results as the relatively larger and older water works basins. In our present time the problem of treating industrial wastes has intensified the search for efficient sedimentation units that would cut down the first costs and maintenance expense of treating large volumes of non-revenue producing wastes.

Not too many years ago, the author's grandfather was practicing as a consulting engineer and designed several water treatment plants. In those good old days, since materials and labor were cheap, no expense was spared, and the sedimentation units were built "plenty large." Today, construction costs have been so increased that even in water treatment plants it now becomes necessary to study the settling basin prob-

lem in order either to reduce the cost of those units or to make present units do more work.

Studies of Flow-Through Settling Tanks

For a period of several years the author has been making studies and collecting data on full-size operating plants in an attempt to learn how to obtain greater sedimentation efficiency in relatively smaller units. This study has been carried on by the use of dyes, calcium chloride and finely divided slurries made up of paper particles or aluminum powder carried along in suspension.

The dyes were used to determine routes of short circuiting, distribution over the net area, flowing-through periods and general water mass movements. It should be borne in mind that water is not displaced in the tanks but actually meanders through them, either in large mass movements or in well defined relatively high-velocity paths or currents, which is what is meant by "short circuiting."

Calcium chloride was used to obtain a graphic determination of the flowing-through period of sedimentation basins in accordance with Professor Charles G. Hyde's method of computation * (1). Effluent samples were collected and titrated and the chloride content plotted for graphical determination. Using the center of gravity of the area under the curve, the flowing-through efficiency was computed. Also, by plotting individual sampling stations it was possible to determine whether one part of the tank was giving more or less than average performance.

It is of interest to note that tanks with no short circuiting showed displacement efficiencies of from 10 to 30 per cent, whereas some of the later and more efficient designs tested have shown flowing-through efficiencies as high as 85 to 90 per cent—certainly all well above 70 per cent.

Finely divided particles of calcium carbonate, aluminum powder, paper punchings and the like have been used to observe flow trends in clear bodies of water and to determine both magnitude and direction of velocity vectors.

Continuous experimentation and observation with many different types of tanks convinced the author that a great many flowing-through units are plagued with shortcomings and more often than not very little or no attention was given to the fluid mechanics involved in flowing liquid continuously through these tanks. Many tanks were found to be exceedingly large so that construction costs and maintenance were wasted. Often, too, the largeness of a tank served no purpose whatsoever because induced currents causing short circuiting allowed liquids to flow through tanks in 15–30 minutes when presumably they should have taken 6 or 8 hours.

Tanks were found without baffles, or with baffles placed so improperly that they acted as training walls and actually induced movement of water along or through well defined cores to produce vicious short circuiting.

Other tanks were found to have effluent weirs that caused accumulative velocity in approaches, which in time would actually reach down into the slurry blankets and pull volumes of

* A commonly used method was night observation; the movements of these fine particles in a beam of light could readily be seen, and velocity values obtained. This trick was unusually successful in revealing tank eccentricities and showing the formation and paths of tendencies.

turbid water over into the effluent.

Another factor that manifested itself, particularly with activated sludge and lime softening, was the occurrence of density currents which became particularly obnoxious in the more economical short-period sedimentation devices.

The manner in which suspended density is unloaded so as to avoid density currents is important. A safe lowered from a one-story window with a winch will cause no disturbance. The same safe pushed off the sill and allowed to fall free will create, at the bottom, *some* splash! In not giving suspended density any consideration we are creating "some splash" in any settling tank carrying a density load such as activated sludge or lime softening slurry.

During the past ten years, the author has tried different tank forms, shapes, depths and methods of leading the water in and out of the tanks to increase their flowing-through efficiency. This work has progressed rather slowly because of the inadvisability of attempting too radical a departure from so-called standard practice and also because of the lack of opportunities to use radical types on a large-plant scale.

There has been steady improvement, however, and it can now be said that as efficient sedimentation can be obtained in a tank having a 60- or 90-minute detention period as in one having a 6- or 8-hour period, provided careful attention is paid to the factors causing "tendencies" and blowups.

Velocity Energy

An external factor that should also be given consideration is the relative state of agitation of the liquid entering the settling zone. The kinetic energy carried by water from one part of a vessel to another, even though baffles are interposed, is rather difficult to dissipate. These eddies tend to carry on and on, and die out only very reluctantly after protracted periods of quiescence are established. The larger tanks are more susceptible to this and, although agitated water in a beaker will quiet down rapidly, it takes much longer for motion to cease in a large tank. Also, continuity of flow through a tank aggravates any motion and builds up the tendencies which become the "thunder heads" of a settling tank.

Influent Devices

With cross-flow tanks it has been found that the best influent devices were those which allowed the influent to be directed quietly into the tank from reasonably spaced influent conduits which would give good distribution over the influent cross-section.

A sizeable amount of the influent end of the tank should be partitioned off by means of a permeable baffle. One end of the tank is then used for the dissipation of entrance and density current eddies. The permeable baffle is so constructed that it does not cause training or collecting and build-up of velocities, but instead allows minor eddies to escape through itself; yet at the same time the baffle offers resistance against free flow in order to confine eddies to the head end of the tank and also to maintain good distribution across the tank cross-section.

In dealing with inlets and outlets, it can be seen that continuous-flow tanks are vastly different from their fill-and-draw cousins. Continuous flow induces tendencies, and tendencies can upset all "average" calculations. Tendencies in extremely low-velocity flowing-through tanks are caused by minute forces all acting in the same direc-

tion, which, bit by bit, pick up momentum until they manifest themselves as a stratum of fast-moving water rushing through quiescent water along well established shearing planes or as vortexes, swirls and eddies.

Effluent Devices

Draw-off troughs on cross-flow tanks were placed in multiples or groups at the effluent end of the tank, and sometimes over the entire surface area, in order to decrease the overflow velocity. Effluent weirs on vertical-flow tanks were placed so as to work a maximum of the tanks' surface in order to reduce the actual velocity of rise and to eliminate the danger of high velocity of approach which might induce localized high velocity rise areas.

The author has observed tanks having effluent weirs so spaced and proportioned as to draw liquid more or less from the surface with little velocity of approach to the weir crest. That is, when the region adjacent to the weir was charged with particles of aluminum flake or dye streamers of potassium permanganate, it was seen that only the water very near the weir edge was accelerating and rushing over. All other particles in the area remained motionless, or moved very slowly yet progressively toward the effluent. Then, if the overflow rate was, say, tripled, it would be observed that particles quite deep and far away were beginning to accelerate rapidly and pass toward the weir. This progressive acceleration of particles continued deeper and farther into the tank. That was the start of a tendency. Sometimes these high velocity regions would penetrate far enough into the tank to start bringing up previously settled sludge. Dyes sometimes would demonstrate that these tendencies were connected and showed short circuiting of influent to effluent.

Computed Displacement Velocity

In both horizontal-flow and vertical-flow tanks, the average flowing-through velocity was held down below known, safe figures which were found by actual experience in large-plant operation to give satisfactory results. This meant that it was no longer possible to proportion tank lengths in percentage of their widths. If there is an ideal or desired average flowing-through velocity, then for that given velocity the length of the tank would be fixed for a given flowing-through period, regardless of the size of the plant.

Double-Flow Tanks

This discovery led to the development of so-called double-flow tanks which actually consist of two or four cross-flow tanks arranged back-to-back on one vessel so that maximum efficiency in construction is obtained. Two general types of double-flow tanks have been developed which were found to be extremely efficient. One type has the two influent ends in common; the water enters the middle of the tank and flows both ways toward effluent ends. In the other, the effluent ends are together; the water enters the two opposite ends of the tank and flows toward the middle. The former is the simplest to build and work into a flow sheet.

A double-flow settling tank was built about one year ago for the Burlington, Iowa, water treatment works. This tank, 110 ft. by 40 ft. by 22 ft., has given creditable performance and can handle flows over and above those ordinarily expected for a tank of its size. The Burlington tank was designed with two influent compartments, each at the

middle of one-half of the tank, so that influent enters the tank at two points and flows simultaneously in four directions. In actuality this tank is four settling tanks built into one. The two-sided effluent weirs on this tank were placed more or less continuously at 9-ft. intervals and covered the entire surface of the tank, so that the average surface rate is the actual surface rate.

The overflow rate on these weirs is a little over 5 gpm. per ft. The vertical rise rate on this tank is about 1.2 gpm. per sq.ft. at the working surface area. This plant alum-treats water taken from the Mississippi River for turbidity and color floc removal, and it is absolutely necessary that the overflow of the tank be of exceptionally low turbidity at all times in order to insure a taste-free water in the system. The effluent turbidity of this tank was consistently averaged about 1 ppm., with extremes ranging from 0.75 ppm. to 2 ppm., and in all ways the performance of the tank has been creditable. The detention period (the filling period for the upper 15 ft.) of this tank is 90 minutes at 5,000 gpm., and a displacement test run on this plant showed the flowing-through efficiency to be well over 90 per cent.

This tank is a fine example of what can be accomplished by careful consideration of the fluid mechanics of sedimentation and shows that when expense or space is at a premium it is possible to obtain entirely satisfactory results by the use of much smaller filling periods than has hitherto been standard practice.

Summary

It is the author's belief that a great many settling tanks today that are overloaded and inefficient could be economically increased in capacity by simply converting the present units to double-flow tanks. Such conversion would be particularly advantageous for around-the-end tanks, which are often subject to short circuiting and inefficiency in displacement.

A great deal that has been learned about sedimentation in the activated sludge and industrial waste field could be transplanted directly into the water works field. There is a strong likelihood that in the future high construction costs will force water works men to give more consideration to obtaining greater efficiencies in sedimentation devices by careful selection of baffle and basin design, rather than by the old "tried and true" method of using very large basins.

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War Housing Priorities

Regulations 1 and 2

Effective August 15, 1946, Housing Expediter Wilson Wyatt issued two orders relating to disposal of federal surplus material which may have some measurable effect upon the progress of the housing program and the provision of utility service to new housing areas.

Regulation 1 covers surplus materials which can be used in building a home. Regulation 2 covers "Surplus Materials and Equipment for *Utilities* Servicing the Emergency Housing Program."

The order provides for the channeling of certain surplus materials and equipment controlled by the War Assets Administration into the construction and maintenance of utilities (*water,* power, gas or sewerage) which are necessary for housing projects. The WAA is forbidden to dispose of certain classes of surplus materials except as directed by the Housing Expediter. Utilities needing such materials for their part in the housing and having knowledge that it is available in a War Assets Warehouse may, during a 15-day period prior to regular public sale, purchase the material needed. The form of certificate they are required to use in this instance reads as follows:

The undersigned certifies to the War Assets Administration and the Housing Expediter, subject to the criminal penalties of sec. 35 (A) of the U. S. Criminal Code, that all the materials and equipment covered by this purchase order (1) are required for construction or maintenance of utilities (water, power, gas, sewerage) necessary to service housing accommodations for which priorities assistance has been assigned under the Veterans' Emergency Housing Program, or construction for which priorities assistance has been assigned under the Veterans Administration Construction Program, to which the following project or serial number or numbers have been assigned: —————— and (2) will be used within 90 days from the date of this purchase order in such construction or maintenance (or may be used within the 90 days, for the repair of an essential utility servicing other housing accommodations, in order to meet a public emergency in connection with such utility which endangers the health or safety of a community, but will not be used for normal maintenance, repair, or operation of such utility).

Both publicly and privately owned water works may purchase under the terms of the order.

The material which the War Assets Administration is required to set aside under this order includes the following water works items:

Corporation cocks, brass, up to and including $1\frac{1}{2}$-in.; Goosenecks, lead, with and without brass fittings, up to and including $1\frac{1}{2}$-in.; hydrants, fire, all types; jute; lead, calking; meters, $\frac{5}{8}$-in., $\frac{3}{4}$-in., 1-in.; meter boxes, frames and covers (all types); pipe: (a) asbestos-cement up to and including 24-in.; (b) black, wrought galvanized iron (services) up to and including $1\frac{1}{2}$-in.; (c) cast-iron pressure, up to and including 24-in.; (d) steel mains up to and including 12-in.; pipe fittings: (a) cast-iron and asbestos-cement (mains) up to and including 24-in.

and stops; (b) black and galvanized iron (services) up to and including 1½-in.; (c) couplings and fittings for steel pipe; tubing, copper and copper alloy, up to and including 1½-in.; service boxes, cast-iron; valves, up to and including 24-in.; valve boxes and covers, cast-iron.

Be Reminded that *publicly owned* water works will continue to be eligible for 40 per cent discount from fair value on their purchase applications, if approved by the U.S. Public Health Service Engineer located in the regional field office of the War Assets Administration. This procedure has been in effect since the beginning of 1946. A U.S. Public Health Service Engineer is stationed at every regional WAA office in order to facilitate purchases by publicly owned water utilities and other state and local public agencies. On August 19th it was also announced that the U.S. Public Health Service Engineers would be stationed in each regional NHA office. These engineers will work under the direction of the regional housing expediters and in co-operation with state and local officials.

Water Works Men Should Proceed as Follows:

Get on the WAA surplus mailing lists for materials shown in Housing Expediter's Priorities Regulation 2 (August 15, 1946) under the heading "Table of Materials and Equipment Covered by this Regulation" (digested above). If such a list is received from WAA and needed material is shown in the list, first inspect it (if possible), then price it, and then order it.

Use the certificate form quoted above on the order. If the water works is publicly owned, the U.S. Public Health Service Engineer will certify that the order is subject to 40 per cent discount.

Assistance in Obtaining Water Works Material

Every water works man responsible for procuring construction and maintenance materials should be familiar with the functions of the below-named men. They will be able to assist in obtaining priorities and in expediting the supply of needed equipment.

Arthur E. Gorman, Director, Public Service Div., National Housing Agency, 7204 Temporary E Bldg., Washington, D.C. (Telephone: Republic 7500—Ext. 3437 & 3438). Mr. Gorman handles problems of additional material needs related to housing.

Paul Valle, Chief, Utilities Branch, Civilian Production Administration, 4653 Social Security Bldg., Washington, D.C. (Telephone: Republic 7500—Ext. 71716). Mr. Valle's duties are to assist water utilities in obtaining needed materials insofar as the CPA is geared to do so under present circumstances.

U.S. Public Health Service Engineer representatives located in each War Assets Administration regional office. It is the duty of these representatives to facilitate the purchase of needed materials by water works if such materials are to be found in their particular areas.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

ALGAE CONTROL

Alga Control in Water Supplies. Max Gelfand (Dallas Power & Light Co., Dallas, Tex.). Power Plant Eng. **50**: 1: 63 ('46). New algaecide described. Cu salts are basis but through use of aliphatic hydroxy acids possible to prepare soln. from which Cu will not ppt. in alk. waters. Citric acid salt selected. In use concns. from 2.5 to 5 ppm. Cu should be maintd. At this concn. growth of most hardy algae either stopped or greatly retarded. As reagent reactive and consequently removed in use, new chems. must be added until equil. estd. Effective concn. below max. of 3 ppm. set by Public Health Standards. Citric acid and Cu sulfate easily available in commercial form and stored in powd. mixt. not changed in storage. In use, Na citrate retards pptn. of Ca salts and where water corrosive owing to H_2S or org. matter, chem. reactions definitely retard corrosion.—*C.A.*

Chemical Methods for the Control of Algae and Scale. Ray Sanders. Brewers Digest. **19**: 53 ('44). Author discusses use of H_2O in beverage industry and problem of alga and scale control. Brief description of algae given with special reference to habitat and temp. relations. Use of algicides considered and attention called to ability of becoming resistant to increasing concns. of these chems. Problem solved by employing 2 algicides with alternate use of effective dosages. One contained sulfate and fluosilicates; the other, pentachlorophenol. Treatment begun with either compd. and continued until resistance appears, when use of second compd. initiated. Cycle continued indefinitely with complete control of algae at very low cost. Suggested that 1 lb. algicide per 1,000 gal. of circulating H_2O gave adequate alga control. Loss of heat-transfer capac. as result of hard H_2O scale formation also discussed. Chems. recommended to be added to H_2O at level of 1 pint of H_2O-treatment compd. per 1000 gal. H_2O. Use of chem. methods of alga and scale control replaces laborious and costly overhaul procedures. Several photos demonstrate alga growth and scale formation on steel pipe.—*C.A.*

Factors Influencing the Growth of Algae in Water. Rudolph E. Thompson. Can. Engr.—Wtr. & Sew. **82**: 10 : 24 (Oct. '44). Brief general discussion with particular reference to L. Ontario at Toronto. Normal algal pop. of vast bulk of L. Ontario water low, probably due to low temp., high org. purity and relatively low ratio of surface to total vol. Water in vicinity of shore, on other hand, frequently contains large no. of organisms. Conditions affecting growth are interrelated and determinant in specific situation is probably one among many possible factors which has been deficient. In L. Ontario water, temp. appears to be important factor.—*R. E. Thompson.*

A Copper Sulfate Test for Algae Control. William D. Monie. Taste & Odor Control J. **10**: 1 (Aug. '44). Practical and simple detn. of correct dosage of copper sulfate to control various species of algae under different conditions of water characteristics and temp. found successful after 1-yr. trial at Canoe Brook Res., Milburn, N.J., using copper sulfate demand test (D.M. test) in which series of samples treated with copper sulfate soln. in 1 lb./mil.gal. steps, stirring ½ hr. in mixing

machine (or shaking for min. or so manually if equip. lacking), adding several drops of phenolphthalein indicator to portions in Nessler tubes, and comparing depth of color with that of blank. Correct concn. of copper sulfate indicated by sample showing strongest color. If high carbon dioxide content prevents coloration of phenolphthalein, all samples first alkalinized with equal vol. of N/88 sodium hydroxide as detd. by prelim-titration with a blank. Copper sulfate increases alky. of algae-laden water, but after proper dosage reached alky. reverts approx. to that of blank. Alky. of distilled water or well water without algae unaffected by D.M. test, but addn. of algae to distilled water causes sharp D.M. color reaction. Filtrates from algae-infested samples also show D.M. color test, indicating that reaction involves oil fraction. Necessity for application in reservoir detd. by microscopic examn., having established limiting densities for various types. Observations indicate critical temps. for succession of species. Method of application consists in hauling 2 burlap bags suspended on frames on either side of outboard-motor-propelled boat. Addnl. chem. added as needed to keep amt. of exposure uniform. Traverses made so that salt proportioned to vol. of various sections of reservoir.—*P.H.E.A.*

Sewage, Algae and Fish. F. J. Brinley. Sew. Wks. J. **15**: 78 ('43). Characteristics of different regions of streams pold. by sewage described. Effect of sewage on fish greater in warm weather than in cold weather because in warm weather fish more active and require more oxygen; at same time, concn. of D.O. in water decreased by high oxygen utilization rate of bacteria decomposing org. matter and lower soly. of oxygen in water than in cold weather. Fish under ice may also die from suffocation when oxygen in water consumed by decaying org. matter. Hydrogen sulfide and other compds. produced during anaerobic decompn. of sludge at bottom of streams to which sewage discharged may cause death of fish. Goldfish have been killed in 96 hr. or less in hard water contg. 10 ppm. hydrogen sulfide. Deposition of sludge makes bottom of streams unfit sites for laying of eggs by fish; eggs already laid may be smothered. Pold. stretches of streams may act as barriers to migrating fish. Algae serve directly or indirectly as food for all fish. End products of decompn. of sewage act as fertilizers for aquatic plants. Photosynthesis in algae increases content of D.O. in stream during day but because algae consume oxygen in respiration there may be rapid fall in concn. of D.O. during early hours of morning. Photosynthesis also removes carbon dioxide from water; fish very sensitive to concn. of this gas. M. M. Wells has shown that fresh water fish tend to move into water contg. 1 to 6 ml. of carbon dioxide per l. Removal of carbon dioxide by plants also causes pptn. of calcium carbonate in hard waters and tends to keep water from becoming acid. H. W Brown and M. E. Jewell have shown, however, that fish can tolerate pH value as low as 4.5.—*W.P.R.*

Maintenance of Base-Exchange Softeners. T. M. Johns. Southern Power & Ind. **64**: 2: 85 ('46). Badly pold. zeolite can be detected by washing sample from top of bed in Erlenmeyer flask; zeolite settles out and suspended matter visible above zeolite. Clean zeolite feels like sharp sand, whereas algae-pold. zeolite feels soft, slippery, and mushy. Procedure for killing and removing algae given, which includes removing and discarding top 2" of zeolite, washing, chlorination and rewashing, after which new material added to restore original depth.—*C.A.*

Troubles Due to Micro-organisms. Rudolph E. Thompson. Can. Engr.—Wtr. & Sew. **82**: 1212: 21 (Dec. '44). Brief general discussion of difficulties due to algae and methods employed to combat them. At Toronto, diatoms, chiefly *Asterionella* and *Synedra*, in L. Ontario water reduce filter runs in slow sand plant each spring. Water flows directly from lake to filters without sedimentation and only feasible measure to combat situation is more frequent raking and scraping of filters. Application of Cl or $CuSO_4$ to water entering filters ineffective. Algae, in numbers experienced at Toronto, do not affect filter runs in drifting sand plant, despite fact that here also water passes directly to filters without sedimentation. Apparently drifting sand principle very effective in preventing clogging of sand by algae.—*R. E. Thompson.*

Slime Control in Cooling Equipment With Phenol Derivatives. J. A. Holmes. Proc. Ann. Water Conf., Eng. Soc. Western Pa. **3**: 61 ('42). Na *m*-chloro-*o*-phenylphenoxide used in controlling coliform and iron-consuming bacteria, yeast and mold. Na tetrachlorophenate used to control sulfate-reducing

bacteria, while Na pentachlorophenoxide used for spore-forming bacteria, yeast organisms, fungi or molds and (with $CuSO_4$) algae. Doses range from 5 to 20 ppm. Control accomplished by inhibiting growth and without introduction of corrosive substances or necessity of destroying all org. matter present.—*C.A.*

The Control of Fouling Organisms in Fresh- and Salt-Water Circuits. John G. Dobson. Trans. A.S.M.E., **68**: 247 (1946). Report deals with macroscopic fouling organisms, referring to slime producers only incidentally. Organisms not only retard flow by increasing friction and interfering with heat transfer but also, when dislodged, block valves, hydrants and sometimes completely close off tube sheets. Mollusca are most troublesome and Mytilus edulis, or the edible, black mussel, is most common; female may release as many as 25,000,000 eggs. First cell division is complete within twenty minutes after fertilization; after 44 hours intermediate changes have been completed and the individual is attached to some stable material. Food material consists of organic matter either living or dead so that moderate sewage pollution speeds growth. Normally shell is slightly open to permit circulation of water but closes within a fraction of a second at any disturbance and remains closed for an extended period. Thus, control by poison difficult in adult stage. Pecten, or scallops, create problem only in isolated instances. Life history of fresh water mussels differs in that eggs are fertilized while still within mantle and parasitic period on host fish necessary before metamorphosis into shelled forms. Porifera (sponges) simplest form of fouling micro-organisms; no truly specialized organs. Sexual reproduction responsible for development of new colonies. In larval stage poisons are most effective method of control. Bryozoa, often confused with seaweed, hold fertilized eggs in inner cavity until larval stage reached or parent dies; then discharged through special openings. Statoblasts, similar to spores, resistant to drying and also to temperatures ranging from 31° to 130°F. Barnacles are crustacea and one of best known of fouling organisms. Eggs hatch in mantle cavity and released as free swimming forms which go through metamorphosis before attaching to solid surfaces. Tunicates highest fouling organisms; one of few animals able to synthesize cellulose. Eggs fertilized after release into water, after which go through several changes and become attached after a period varying from 160 to 450 hours. Tunicates have specialized organs including a nerve cord and gangula. Control methods must be applied during active larval stage. Earliest control method was heating circulating water to a lethal point. This expensive and reduces plant efficiency. The dislodged organisms removed by screening. Change in salinity may be effective. Early mariners ran ships into fresh water to loosen barnacles. Method is not completely satisfactory because some organisms thrive under varying degrees of salinity. In some plants spring rains often change the normal water supply from salt or brackish to fresh at which time quantities of fouling organisms dislodged to clog pipelines and blanket tube sheets. Removal of oxygen effective but no practical means for such volumes of water. High velocity in tunnels and lines prevent these forms from becoming attached but cost of pumping, because of friction, excessive. Values of pH under 5 can remove many forms. Sea water well buffered and considerable quantities of acid are required. Cost out of proportion. Also, low pH water corrosive. Anti-fouling paint lasts only about a year and, since porous, must overlay resistant paint. Active poisons (cyanide, mercury and arsenic compds.) effective but cannot be used if objectionable in receiving water. Application of free available residual chlorine, at a little under 1 ppm., used continuously will loosen already attached adult forms. Care in application must be taken so that the entire deposit is not disturbed at once in order to avoid stoppage of pipelines and tube sheets. If concentration is increased gradually, the organisms are killed only few at a time. With knowledge of the organisms responsible for the fouling and of their breeding season, intermittent treatment on a program found to be effective will kill the larval forms with as little as 0.5 ppm. of free available residual chlorine. The frequency of the application of chlorine and its concentration varies for different organisms. Between times, intermittent use of chlorine will prevent growth of slime organisms which interfere with heat transfer. Paper is unusually complete; 106 references; discussion by men representing widely different interests, therefore quite broad. Excellent life histories of fouling organisms given.—*C. K. Calvert.*

CHEMICAL FEEDING, CONDITIONING AND SEDIMENTATION

Research Relating to Sedimentation. L. B. Escritt. Surveyor (Br.) **104**: 299 ('45). Design of pptn. and sedimentation tanks not yet satisfactory; more research on subject required. According to Hazen's theory of sedimentation, for settling particles of such size that they obey Stokes' law, tank should provide period of retention such that particle would fall from surface of liquid to bottom of tank within this period. If 2 tanks have equal surface area but different depth, greater capac. required in deeper tank to provide longer period of settling. Hazen concluded from this that eff. of settling at given rate of flow depended on ratio of capac. to depth. In practice, however, fluids usually contain particles of varied size and may include those too large to obey Stokes' law, as well as colloids which can be removed only by mech. flocculation or chem. treatment. Eff. of sedimentation also depends on arrangement of inlet and outlet and on prevention of turbulence within tank. In most modern tanks for sedimentation of sewage, liquid enters below level of liquid in tank and outlets are arranged to draw off thin layer of surface water. Therefore, suspended particles that pass out of tank must have risen, proving that there are forces present which work against force of gravity. These forces include eddies produced by dissipation of energy due to reduction of velocity of flow at inlet, changes in velocity due to cross baffles, and friction between liquid and sides of tank. Further large-scale expts. required to det. relation between depth and surface area and between length and breadth. Sedimentation not merely simple mech. problem, however, and certain amt. of turbulence may assist flocculation and improve effluent. Although natural waters and sewage contain particles of different size and in different concns., can be stated in general, that for both continuous flow and quiescent settling, amt. of suspended matter remaining unsettled varies approx. as function of period of retention.—*W.P.R.*

A Fresh Approach to the Problem of Precipitation Tank Design. Ian M. E. Aitken. Wtr. & Wtr. Eng. (Br.) **48**: 320 (Midsummer '45). Two main factors which appear to govern usual design adopted for pptn. tanks: (1) Retention period of about 3 times period required to obtain desired degree of settlement in still water—as in jar test. (2) Equally spaced over-and-under baffles so arranged as to insure even rate of flow throughout tank. Numerous glass jar tests carried out using alum and sodium aluminate as coagulants. Some deductions from observations were: (a) Settlement of, say 90% of floc produced, continues for period called "bulk settlement period." (b) Bulk settlement period in jar tests may be reduced by increasing mixing period or by introducing slow-stirring stage immediately after mixing. (c) By proper selection of relative periods of mixing, aggregating and settling, over-all period of time occupied may be considerably reduced. (d) With introduction of aggregating (flocculating) stage avg. rate of pptn. of floc particles at highest shortly after commencement of settling stage. (e) Careful introduction, at aggregating stage, of charge of presettled floc speeds up initial settling rate. (f) Introduction of slow-stirring stage about half way through bulk settlement period does not secure noticeable improvement. Study of floc settlement in water flowing through two 4½" bore, 5' long parallel glass tubes (arranged in series) suggested these considerations: (1) Downflow sections of usual design, representing about 50% of total tank vol., contribute nothing to sepn. of flocculate from water. (2) Only remaining value of downflow sections is retention period which they represent; formation of floc would be more efficiently accomplished by providing addl. upflow sections in their place. Downflow sections should be designed solely for purpose of conducting water to bottom of next upflow section, leaving upflow sections to combine requirements of retention period and floc removal. In next test, rate of flow through exptl. equip. adjusted to a retention period of 2¼ hr. Veloc. of upflow was 0.0815 fpm. Inflow sample contained in suspension 92% of total floc of jar test, while half-way sample contained only 5%. Outlet samples showed that less than 0.25% of total floc was being carried away to dischg. in exptl. equip. In tank of normal size, employing 2 upflow

sections of 5′ height or 1 section of 10′ height would result in relative dimensions at once conducive to short-circuiting from inlet at bottom of one side to outlet at top on other side. Eddies so produced would destroy all semblance of steady vertical upflow veloc. and result in unsatisfactory performance. Arrangement would represent reversion to large rectangular tank without baffles—known to be impracticable for sedimentation purposes. Consideration of results suggested that final upflow veloc. of about 0.15 fpm., in conjunction with total retention period of 2¼ hr., would approx. desired performance in large-scale pptn. tank. In exptl. design with 4 upflow and 4 downflow sections, following sectional retention periods allowed: 4 down sections, 0.3 hr.; first upflow section, 0.3 hr.; second and third sections, 0.92 hr.; and fourth section, 0.98 hr. Performance in expts. in model tank, 1′ 3″ wide, 3′ 3″ long and 1′ 6″ deep, almost exactly reproduced results which had been aim of theoretical basis of design. These principles of design employed, in tropical countries, for several pptn. tanks installed for settlement of chemically treated river water prior to filtration. Operating results confirmed conclusions. Some novel details of constr. include: Baffle walls 5½″ thick—single-width brick with ½″ of plaster on each side. "Over" and "under" baffle walls enclosing each downflow section joined, for sake of rigidity, by short cross walls which divide each downflow section into series of rectangular shafts. Possibility of differential pressure between opposite sides of baffle prevented by hanging gate hinged on top edge, built into baffle wall near bottom. To distribute flow as evenly as possible 4½″ brickwork cross walls of varying lengths provided at right angles to baffle walls. Static pressure due to depth of water in tank can be utilized to dischg. sludge at level which is only few inches below water level in tank. Design described differs from conventional design with equally spaced baffles only in respacing of baffles and reduction of tank size which respacing permits. Application of author's proposals to circular design of tank affords advantages for following reasons: (1) For same vol. smaller quant. of bldg. material required. (2) Desired increase of vol. in successive upflow sections obtained by more nearly const. avg. section width, due to successively increasing avg. diams. of upflow sections, so that ratio of width to depth is not greatly increased in later upflow sections, thus insuring more even distr. of upflow veloc. at any particular level. (3) Use of conically disposed baffle walls enables each upflow section to be designed so as to produce gradually reducing water veloc. in manner which corresponds more exactly to continuously changing avg. speed of floc settlement in jar tests. Experience with tanks designed according to these principles supports contention that retention times can be halved by their adoption. *Discussion.* J. T. Calvert: Expts. reported by author started in Georgetown (Br. Guiana) where scale models constructed. Same principles adopted in India for settlement of industrial waste water as well as for water supply. In model expts., important that depth of model and prototype be the same, otherwise interpretation of results involving upward velocs. well nigh impossible. In case of large tank, short-circuiting is greatest handicap to proper sedimentation. Disadvantage of upward flow tank is depth of excavation required and consequent increase in cost. Circular tank should be decided improvement on rectangular design. E. G. B. Gledhill: Designs for both pptn. tanks and retention tanks seek to cause water to be displaced uniformly and prevent short-circuiting and formation of eddies, but pptn. tanks must keep veloc. within limits. Ratio of width to depth important consideration. In pptn. tanks veloc. below critical (laminar flow) and temp. effects may be considerable. In horizontal-flow tanks, without baffles, no upflow and floc settles out. Downflow section of tank should have appreciable effect on sedimentation. Concern in sedimentation tanks is with max. filament of veloc. and not avg. flow. Particularly true with holding tanks in chlorination where definite contact time is necessary. H. W. Caulson: Paper lacks certain details which would have enhanced value. In '39 paper published by Inst. of Civ. Engrs. described expts. on design of circular sedimentation tanks. Lack of data makes it difficult to form judgment of effectiveness of tanks author describes. Slightly acid peaty waters colored like "tea without milk" have been treated successfully in pressure filters without sedimentation in tanks. Purif. plant constructed in '28 which included rectangular sedimentation tanks. To use author's design would have occupied greater area and introduced difficulties and expense. Plants having rectangular sedi-

mentation tanks clarifying waters up to 200° Hazen have been working successfully for 15–30 yr. Author refers to river waters without giving approx. figures for suspended solids. Were they like Thames, with less than 70 ppm., or Tigris and Euphrates, with 7000 ppm.? In Britain, Severn R. probably worst, with 100–150 ppm. If London's river supplies had to be obtained from sources similar to those mentioned, would be necessary at times to dispose of 7000–8000 gpm. (Imp.) of thick slurry, which, if dried, would yield 4 tons of powd. per min. Questionable whether author's tanks would handle such waters. Fallacious to draw conclusions on cost of tanks on basis of relative amts. of constr. materials alone. J. R. GRIFFITHS: Author appears to have lost sight of fact that eff. of settling tank depends largely on deg. of aggregation achieved. No attention seems to have been given to increasing size and settling rate of floc. In Br. practice, no. of modifications of baffled horizontal-flow tanks have been used. Also, both horizontal and vertical mech. flocculators used. Appears that author's deductions based on behavior of one or limited no. of waters. Nominal retention period is seldom governing factor in settling tank design. Important features are upward veloc., specific gravity and size of floc to be settled. Author has come to false conclusion that for simple inverted cone type tank, depth equiv. to sum of multiple compartments would be necessary. Author's conclusions open to following criticisms: (1) Design elaborate and costly, and efficacy of sludge removal arrangements doubtful. (2) Vertical-flow system can be utilized in less costly manner and sludge removed with greater ease. (3) Author's system does not make use of sludge blanket principle. (4) Justification for design of complicated system of baffles would appear limited to conversion of existing horizontal-flow tank. *Discussion. Ibid.* **48**: 539 (Oct. '45). C. W. CASSE: In India, offices of water purif. and other specialist firms situated mainly in Bombay and Calcutta, probably hundreds of miles away, so engr. left much to his own devices. At Cawnpore, turbidity of raw water varies from 2000 ppm., during rainy season to as low as 25.5 ppm. at other times during year. One of first vertical hopper sludge type sedimentation tanks installed at Dehra Dun in United Provinces. Doubtful if it would be economical to apply this design to large water works supplying over 20 mgd. (Imp.). Unfortunately economic size and retention capac. of tank limited by hopper design, but not same limitation in case of author's rectangular and circular tanks. Success of hopper bottom upflow settling tank confirms author's theories, but whereas this design attempts to do everything in one tank section, author contends that it is better to control flows more positively and, by means of baffles, to divide tank into series of upflow sections, each designed to work at definitely controlled veloc. *Author's reply:* Between submission and reading of original paper, author realized that he was by no means alone in opinion that complete departure from classical design overdue. Water engrs. will be more inclined to respace baffles of existing rectangular tanks and thus obtain recommended grading of upflow velocs., or to adopt one of proposed circular designs in installation of new works. Raw water on which expts. conducted derived from irrigation conservancy consisting of 100 sq.mi. of inundated swamp land. Range of color experienced 375° to 1800° Hazen. pH range 4.3 to 6.2. Rapid changes of color sometimes experienced. High turbidity values not involved. Expts. conducted and suggested tank designs evolved, with regard to formation, aggregation and pptn. of floc under conditions which appear to present greatest problems, i.e., with ultra-light floc resulting from chem. reaction on purely colloidal matter. Author did not have opportunity to try out theories in practice. However, 4 filters converted at steel mill into pptn. tanks operating on author's principles. As result, through-flow rating of plant increased 3½ times original value. Simple elementary fact that highest possible eff. of sepn. of ppt. in continuously-moving body of water achieved when water flow of opposite direction to, and less than, veloc. of settlement of ppt. relative to water. Conversely, where both fluid and ppt. move in same direction, as in body of downfiow section, no such sepn. can possibly be effected. In reply to those criticizing sludge dischg. arrangements, must reiterate that none of tanks constructed; purely suggested designs, but incorporate features which have been tried out in existing tanks, except for sludge dischg. arrangements. Old rectangular filters, converted to pptn. tanks, operated without experiencing trouble due to sludge coming over with decanted water. This due to fact that final upflow speed insufficient to lift any well-formed floc particles to decanting level. "Nest of pipes"

arrangement to control upward veloc. would prove impracticable because of friction loss and cost and because of difficulty of assuring even distr. of inflow to various pipes, and because of increased surface area presented for algal growths. Author disagrees with Gledhill's suggestion that important factor in design is ratio of veloc. to area at right angles to flow. The lower the upward veloc. the more effective pptn. action. Truly laminar flow more likely to be created in long narrow channel than in square chamber having equal area at right angles to flow. Griffiths questions statement that inverted-cone tank should have depth equiv. to sum of upflow depths in baffled tank of author's design. Theoretical considerations indicate that greatest reduction of retention time will be obtained only when upflow veloc. suitably proportioned to avg. settling veloc. at every instant throughout bulk settlement period; this theory is essential basis of suggested designs. Dixon raised question of adaptability to varying rates of through-flow. Multiple upflow design would show decided advantage in this respect over single upflow design. First effect of increase in through-flow rate is to expand vol. of accumulated sludge, and to raise, with water, floc particles which were barely settling before change. In case of author's designs, swelling of each sludge mass would raise top of sludge accumulation to level at which upflow veloc. reduced, so that restabilization of conditions more rapidly attained. Both Coulson and Griffiths refer to "complicated" arrangement of baffles. Rectangular tank design no more complicated than classical design; only difference is positioning of baffles, and constr. actually simplified.—*H. E. Babbitt.*

Mechanical Flocculation of Water. NEIL MUNRO. Wtr. & Sew. **83**: 8: 23 (Aug. '45). Brief data regarding coagulant savings effected by mech. flocculation at Old Hickory, Tenn., and New Brunswick and Trenton, N.J. In each, reduction in alum dosage of order 30%. Other advantages include reduction in wash water and time required for flocculation.—*R. E. Thompson.*

Improvements in the Coagulation of Surface Waters With Activated Silica. L. L. KLINGER. Paper Tr. J. **122**: 15: 44 ('46). Colloidal SiO_2 used successfully as coagulant aid for both colored and soft lowland waters and turbid and hard lowland waters. Most well-known methods for activation of SiO_2 in Na silicate tried, as well as others, some of which suggested in literature but not applied in actual practice. Principle of continuous feed applied successfully in prepn. of hydrosol. Resultant filtered water less turbid, of somewhat lower color and SiO_2 content, of somewhat higher pH, sparkling and clear. Activated SiO_2 remedies many difficulties attendant upon production of suitable filtered water such as needed in paper industry.—*C.A.*

The Return to "Loess Pampeano" as the Raw Material for the Manufacture of Coagulants. J. C. MIGLIARO. Bol. Obras Sanit. Nacion (Arg.) **13**: 76: 276 ('43). Coagulant used in treatment of water supply of Buenos Aires mixt. of aluminum and iron sulfates. Owing to wartime conditions, import of bauxite, originally used in mfr. of coagulant, impossible. Ore, known as "loess pampeano," mined locally, now used as raw material. Sulfuric acid required in prepn. of coagulant also mfd. locally. Reaction when "loess pampeano" used instead of bauxite less violent but yield of required product smaller. —*W.P.R.*

Coagulant From Moscow Coal for Water Purification. P. V. DYBINA. Khim. Farm. Prom. (U.S.S.R.) **8**: 16 ('44). Ash from generating stations mixed with excess of H_2SO_4 and heated for varying periods, and Al_2O_3 and $Al_2O_3 + Fe_2O_3$ detd. in products. Ash from some of stations suitable for production of coagulant, while from others not suitable.—*C.A.*

Recovery of the Coagulant From Sludge From Sedimentation Tanks at Water Treatment Plants. V. A. KLYACHKO. Vodosnabzhenie i Sanit. Tekh. (U.S.S.R.) **15**: 8: 24 ('40); Gesundh.-Ing. (Ger.) **65**: 420 ('42). Expts. made at water works in Moscow on recovery of alumina used as coagulant. Sludge from sedimentation tanks comprised 96.5% water and 3.5% solid matter, of which 218.8 mg./g. alumina. Sludge treated with lime water of 136° (Ger.) hardness. Calcium aluminate formed in amts. proportional to period of treatment and, up to certain limit, to amt. of lime added. Soln. of calcium aluminate colorless, absorbed 30–50 mg./l. oxygen and did not decompose when kept for 2 mo. at 18°C. Coagulating power of soln. of calcium aluminate greater than that of alumina. Reductions in color and in turbid-

ity greatest when water treated with both chems.; amt. of alumina required then 25–30% less than when alumina used alone. Similarly effective soln. of calcium aluminate could be recovered again from sludge obtained with re-used coagulant.—*W.P.R.*

Pre-treatment of Water for Effective Filtration. C. R. Cox. Pub. Wks., **76**: 5: 21 ('45). Discussion of the use of coagulation and sedimentation in prepn. of water for filtration. Other methods of treating water, such as chlorination or treatment with active carbon, may improve coagulation. Coagulation affected by many factors, most important of which is character of water. Coagulant, such as alum or aluminum sulfate, added to water, reacts with substances present in water or with added alkali, with formation of aluminum hydroxide, which is only slightly soluble at certain pH values. Aluminum hydroxide in excess of soly. value pptd. in form of minute crystals, which, on gentle agitation, become attached to one another in chains or networks. If gentle agitation continued, clusters of crystals form larger aggregates until visible floc formed. Floc has positive elec. charge; suspended solids, bacteria, and some negative ions absorbed by it. If treatment effective, water, after floc allowed to settle, has turbidity not greater than 5–10 ppm. Coagulation with alum in highly colored, soft water, contg. material in colloidal soln., best achieved at pH values of 4.4–6.0; at these low pH values, basic sulfates, rather than hydroxide, formed. Sulfates appear to react directly with colloidal matter causing color. In treating water with coagulant, rapid mixing of water with coagulant required, followed by gentle agitation and finally by sedimentation. Equip. developed in which raw water, coagulant and previously pptd. floc agitated together; by this means coagulation improved. Alum effective coagulant for most natural waters; chlorinated copperas or ferric compd. valuable for treating water which has high or low pH value, particularly when iron or manganese to be removed. Dose of coagulant required depends on temp. of water and contents of suspended solids, org. matter, and mineral matter. Required dose should be detd. by lab. tests. Properties of chems. commonly used for coagulation in water described. Alum may be used for most turbid and moderately colored waters, pH values of which between 5.7 and 8.0. Highly colored waters, in which optimum coagulation obtained at pH values between 4.4 and 6.0, require large dose of alum, addn. of sulfuric acid in conjunction with alum, or chlorination prior to addn. of alum to oxidize iron and manganese which usually present in colored water. When alum used in conjunction with softening by lime and soda, and treated water has pH value between 9.0 and 10.5, floc of calcium aluminate formed. Black alum is alum to which 2–5% by weight of active carbon added; carbon removes tastes and odors from water. Activated alum contains less water of crystallization than does ordinary filter alum and also contains insol. silica to assist coagulation in water only slightly turbid. Sodium aluminate used in conjunction with alum to assist coagulation in water which is cold or which contains very little turbidity. Dose of about 34.24 ppm. of sodium aluminate usually sufficient. Sodium aluminate also used in conjunction with alum for treating highly colored waters. Alum alone or in conjunction with sulfuric acid added to water, which then contains undesirable amt. of free alum; sodium aluminate, and if necessary lime, then added to increase pH value and to form floc of aluminum hydroxide. Sodium aluminate also used in conjunction with lime-soda process for softening turbid water. When copperas used as coagulant, lime must be added to increase pH value to more than 8.5; floc of ferric hydroxide then formed. Copperas used extensively in conjunction with softening by lime-soda process. Amt. of lime required varies with different waters but is about 0.27 g. for each g. of copperas used. When copperas treated with chlorine, ferric sulfate and ferric chloride formed; chlorinated copperas therefore of use where ferric compds. most effective as coagulants. Chlorine required for disinfection must be added in excess of that required to react with copperas. Bentonite, fuller's earth, and similar clays recently used to assist coagulation in relatively clear water; they supply suspended matter which aids formation of floc. Some clays remove substances causing tastes and odors, particularly those of oily nature. Colloidal or activated silica also used as aid in coagulation. Removal of suspended matter from water before filtration allows use of coarser sand or anthrafilt in filters, which in turn increases length of filter runs and facilitates washing of filters. When removal of suspended matter before filtration satis-

factory, filters may be operated at rates somewhat higher than conventional rate of 2 gal./sq.ft. per min. Design of mixing tanks, flocculation tanks and sedimentation tanks discussed. Best results obtained when rate of movement of water in flocculation tanks between 0.6 and 1.2 fps. Periods of retention in flocculation tanks now usually 20–60 min. Methods of studying flow of water in sedimentation tanks described.—*W.P.R.*

U.S. WATER SUPPLIES—GENERAL

New Jersey State Water Policy Commission —Surface Water Supply of New Jersey. *Stream Flow Records.* O. W. HARTWELL. Special Rpt. No. 9 ('44). Rpt. covers 6-yr. period from Oct. 1, '34, to Sept. 30, '40. Contains records of 90 gaging stations in N.J., 74 of which record stream flow, and 16, elevations of water. Convenient reference for those in need of accurate information on flow of streams in connection with problems on water works, dams, reservoirs, bridges, flood control works, drainage works and other problems.—*Ed.*

The Chemical Analyses of the Waters of Oklahoma. OTTO M. SMITH. *Contributors:* ROBERT H. DOTT & E. C. WARKENTIN. Okla. A. & M. College Eng. Expt. Sta. Pub. No. 52 (Oct. '42). [474 pp., $2.50 at College Book Store, Stillwater, Okla.] Okla. unique in that it contains water which varies in amt. of mineral content from only few ppm. solids to satd. brines contg. over 28% solids. Every type of water found in state included in 2935 anals. given in logical and orderly arrangement. Material made clearer by 13 tables, 21 drawings and 15 photos, supplemented by carefully prepd. index. One aim of publication to show, for every city, all available complete mineral anals. of municipal supply and to give such data for sufficiently large no. of local supplies to indicate probable type of water in surrounding territory. Part I made up of 5 chap. (90 pp.) discussing: Uses of Water in Okla.; Geol. of Ground Water Supplies; Hardness; Fluorides; and Methods of Anal. In Part II, anals. arranged in 3 chap: City Supplies, Wells, Lakes, Ponds and Small Streams; Rivers and Large Streams; Mineral Waters and Brines. Arrangement of anals. of first group in Part II alphabetical by counties, giving hypothetical combinations, in ppm. Same order repeated for same waters in ionic anals., expressed both as ppm. and as mg. equivalents per liter (mE/l.). Similarly, hypothetical combinations and ionic anals. given for rivers, divided into basins of Arkansas and of Red, with subdiv. into main rivers and tributaries in each basin. Discussion of medicinal value of certain waters followed by descriptions, with anals. of mineral waters and brines, stated in ppm. and in gpg. Anals. obtained from 3 sources: publications of govtl. agencies and private institutions, unpublished files of business concerns and tests made for this publication.—*Harrison Hale.*

Water Supply and Industrial Development. LORAN D. GAYTON. J. Western Soc. Engrs. **50**: 1: 17 (Mar. '45). History of Chicago water supply system with respect to expansion of industry. Early settlers in Chicago obtained domestic water directly from Chicago R. or, when particular, from peddlers selling Lake Michigan water. In 1834, well dug for public supply. In 1842, Chicago Hydraulic Co. supplied Lake Michigan water to area south of Chicago R. City, in 1851, took over this util. and enlarged it considerably. Intake was 600′ of 30″ wooden pipe at Chicago Ave. Station. Distr. system contained 30 mi. of c-i. pipe and 3 elevated wrought-iron reservoirs, 0.5-mil.gal. capac. each. Due to increasing contamn. by industry, new crib placed, in 1867, 2 mi. east of shore line, and 5′ tunnel placed in service. System since grew to include 6 intake cribs, from 2 to 3 mi. offshore; 63 mi. of tunnels; 12 pumping stations; and about 3800 mi. of mains. Growth of Chicago in 19th century unequalled by that of any other metropolis in any age, increasing from pop. of 50 in 1830 to nearly 1,700,000 in '00. Most phenomenal indus. growth, before '00, was in iron and steel manufactories, with meat packing and men's clothing also dominating. To keep pace, water system pumped 57 mgd. in 1880, and 322 mgd. in '00. During "golden age" of indus. development, from '00 to '20, steel mfg. forged to position just behind Pittsburgh; packing, clothing, furniture and

printing also contributed substantially to placing Chicago's mfr. dollar value of nearly 1,500,000,000, in '14, second only to New York City. In '20, $3,600,000,000 value of products, scattered throughout city, necessitated $36,000,000 extension to water system, including another crib and 1000 mi. of mains, to supply 773-mgd. pumpage. During period '20–'30, while no increase registered in number of industries or wage earners, pop. increased by about ⅔ million people, and $38,000,000 more invested in system to add 2 pumping stations, of 160- and 333-mgd. capac., resp.; 15 mi. of tunnels and over 108,000 services. Through indus. depression from '30 to '39, number of manufactories remained stationary, but with decreased number of wage earners; pop. remained without net change. Principal addn. to water system was 11-mi. Chicago Ave. Tunnel, ranging from 10′ to 16′ in diam. Indus. activity increased from '40 to '43; demand for water by 8300 mfg. industries producing $7,000,000,000 of products hiked from 43 mgd. in '40 to 73 mgd. in '43. Of this stockyards avgd. 32 mgd. Graph shows close parallelism of the water supplied to mfg. classifications in Chicago by years, subsequent to '28, with indus. production of country as a whole. During stockyards fire of May '43, peak pumpage from 94 fire engines at 105-mgd. rate; greater portion supplied from Western Ave. pumping station, which was delivering at 235-mgd. rate. Pipe capacs. ample; pressures usually between 30 to 40 psi., and never dropped below 20 psi. Air-conditioning, minor factor prior to '30, now poses new and accelerating demand. At end of '43, 5505 units, totaling 90,629 tons of refrigeration, widely scattered over city. Sterilization started at cribs in '12, and in '16 entire supply being chlorinated. South Side Filtration Plant, started in '38, will supply 320 mgd. to about ⅓ of pop. In '43, avg. pumpage 975.5 mgd., peak day 1206 mil.gal., and peak hr. 1487 mgd. As of Dec. '42, total investment $191,000,000. Customers pay net 7.4¢ per 1000 gal., claimed as lowest rate for any city in world.—*A. A. Hirsch.*

Philadelphia's Water Works From 1798 to 1944. M. J. McLaughlin. Am. City, **59**: 10: 86 ('44). Historical development of water supply system of Philadelphia, Pa., from 1798 to 1944 reviewed. When water works first constructed, Schuylkill R. only source of supply. As town expanded, however, supply from this source inadequate to meet increased demand and, in order to supplement supply, water drawn also from Delaware R. In time, both these sources became increasingly contamd. and need for providing facilities for treatment indicated. Filtration introduced on partial scale only in 1899, but, by 1911, all water being filtered. At present time, 5 filtration plants, in which primary, mechanical and slow sand filters in operation. Water also given chem. treatment, and samples of treated water analyzed daily. Expts. on use of ozone for control of tastes and odors have been made. Proposed to build extension to Torresdale plant, which has largest slow sand filters in world; this new plant will have rapid sand filtration system.—*W.P.R.*

Improvements Made to Monroe City (Mo.) Water Plant. F. B. Bridges. J. Missouri Water Sew. Conf. **16**: 2: 9 ('45). H_2O supplied to Monroe City, Mo., from 2 lakes. Smaller lake treated with $CuSO_4$ which supplies most of H_2O. Improvements made since '42 include installation of larger aerator with bypass valve and shutters to elim. H_2O blown away by wind, division of sedimentation basin into 2 parts and arrangement so they can be operated in series, in multiple or alone; addn. of 2 rooms to provide for storage of chem., coal, chem. lab.; and better location for chem. feeders. Operation and results of improvements described. Diagram shows old and new arrangement and table gives original design and new design, gallons treated and amts. of alum and lime added. Improvements resulted in 19% saving in alum and 31% saving in lime.—*C.A.*

Water Supply and Sewage Works for the Atomic Bomb City. G. E. Crosby & P. B. Streander. Eng. News-Rec. **135**: 819 ('45). Water supply for Clinton Engineer Works and new city of Oak Ridge, Tenn., (pop. 75,000) derived from Clinch R. 16-mgd. purif. plant consists of gravimetric feeders for application of alum, $Ca(OH)_2$ and Na_2CO_3, latter to filtered water for pH adjustment, flash mixer, 2 paddle-type flocculation tanks, 2 settling tanks, 14 gravity rapid sand filters equipped for surface washing, and chlorination equip. Sewer system dischgs. into 2 separate drainage systems, necessitating 2 treatment plants. One, with capac. of 2 mgd., of activated sludge type and includes grease removal, primary settlement, aeration in air-actuated spiral-flow tanks, secondary

settlement, and chlorination. Sludge digested in 2-stage heated tanks and dried on open beds. B.O.D. of effluent less than that of water of Clinch R., into which it is dischgd. Other plant, which dischgs. into Popular Creek, provides for grease removal settlement, chlorination and sludge digestion and drying. Flow considerably in excess of designed capac. of 3.5 mgd. and plans have been made to employ chem. pptn.—*C.A.*

Villages Like Good Water, Too. BENNETT B. SMITH. Am. City **58**: 83 (Dec. '43). Yates City, Ill., with pop. of 650, built itself a water supply in '37. Improvement financed on revenue bond basis; work set up as WPA project, $52,000 being furnished by village and $40,000 in labor and materials by WPA. Supply consists of 2 shallow wells (6" and 8") driven in glacial drift, pumped by 2 well pumps (80 gpm. and 400 gpm.). Water pumped from wells into 125,000-gal. gravity storage reservoir, then through zeolite softener, and then pumped by 80-gpm. pump into 2500-gal. pressure tank. Distr. system consists of asbestos-cement pipe with careful design which successfully elims. all dead ends in system.—*C.A.*

CANADIAN WATER SUPPLIES—GENERAL

Water Works and Sewage Plants. A. E. BERRY. Wtr. & Sew. **83**: 7: 21 (July '45). Large percentage of Canadian water supply chlorinated. Alum used almost exclusively. Taste and odor treatments include superchlorination, aeration, ammoniation, ClO_2 and C. Survey few years ago showed C consumption in excess of 76,000 lb./yr., avg. dosage being 4.13 lb./mil.gal. and cost 41¢ per mil.gal. treated. Percentage of main sizes: 4", 15%; 6", 47%; 8", 15%; 10", 4%; 12", 9.7%; 18", 1.4%; over 18", 7.9%. Avg. cost of water (125 municipalities) for 5-room house on 45' frontage and assessed at $2000: flat rates $16, metered $14.45. Fire protection charges commonly based on number of hydrants—$40.50 each per yr. Billing periods: 3 mo. 62%; 2 mo. 17%; 1 mo. 9%. Avg. cost of meter reading 25¢ per meter per annum. Avg. cost of gravity rapid sand plants: $11.35 per capita, $67,965 per mgd. designed capac., $159.20 per sq.ft. sand area. Sewage treatment provided in 25% of 550 municipalities served by sewerage systems.—*R. E. Thompson.*

Water Works Systems: A Quarter Century of Development. A. E. BERRY. Eng. Cont. Rec. **58**: 3: 76 (Mar. '45). Public water systems in Canada increased from 700 to about 1300 in last 25 yr., 55–60% of total pop. now being served. Sharpest rise during decade '20–'30, notably in small communities (500–1000 pop.), which directed trend toward use of underground supplies. Practically all pumping stations electrified, with gasoline or diesel engine-driven pumps for standby. Early filter plants of slow sand type, 12 such plants having been built in Canada, last in '22. There are now about 70 rapid sand and 50 pressure filter plants, trend being strongly toward former. Of 30,000,000 ft. of mains, 47% are 6", while 4" and 8" each constitute 15%. About 8' of main required per person served. Services avg. 111 per mi. of main, avg. of 4.2 persons being served by each. Water costs prior to war avgd. $4.83 per yr. per capita, with $2.14 debenture charges. Trend in Ontario toward public utility admin., while in other provinces control largely vested directly or indirectly in city council.—*R. E. Thompson.*

Centrifugal Pump Development in 25 Years. R. W. ANGUS. Eng. Cont. Rec. **58**: 3: 72 (Mar. '45). Centrifugal pumps not in practical use until about 1850 and practically none used for water works service in Canada prior to '00. While steam motive power, reciprocating pump held field and efficiencies attained have never been excelled by centrifugal units under similar conditions. During past 25 yr., progress mainly in eff. and adaptability. Almost universal adoption of horizontally-split casing definite improvement in constr. Balancing end thrust always problem, particularly with multi-stage units. Gain in eff. close to 10%, over 93% being attained in some recent large pumps. Lab. tests and operating results have shown max. suction lift for satisfactory performance depends on specific speed and head. Poor suction conditions have contributed largely to bad performance. Increased eff. largely due to ap-

preciation of need for good workmanship, particularly in hydr. passages. Efficient pumps have very smooth impellers, of good hydr. shape. Axial flow pump overcomes difficulty of producing low heads at high speeds. Objectionable feature is that both head and input power with dischg. valve closed often greatly exceeds operating values, introducing starting problems. Such pumps not ordinarily started against closed valve. Adjustable impeller blades provide remarkable flexibility and eff. and allow for great variations in dischg., but are expensive. Much progress in deep well pumps. Lining with rubber, etc., for protection against abrasion not uncommon but this constr. does not lend itself to high efficiencies.—*R. E. Thompson.*

Water Purification Progress in 25 Years. Norman J. Howard. Eng. Cont. Rec. **58**: 3: 74 (Mar. '45). Review of developments which have resulted in safe and palatable water being delivered to millions of consumers and consequent elimn., in high deg., of water-borne disease. In '44, typhoid death rate in Ontario only 0.2 per 100,000, while in Toronto there has been only 1 (unexplained) death from typhoid in last 3 yr.—*R. E. Thompson.*

Sanitation and Town Planning. James F. MacLaren. Can. Engr.—Wtr. & Sew. **82**: 11: 46 (Nov. '44). Town planning receiving major consideration in postwar planning. As proper perspective must be maintd. and only such works undertaken as are logical and justifiable, provision of adequate sanitation should receive first consideration. In many instances, sanitary facilities can best be provided through joint action of regional authorities. Instances of this in Canada described. Such authorities constitute good foundation on which to build sound sanitation practice. How far to plan in advance of immediate requirements is problem. Basic data required for any planning include topography, methods of sewage disposal, sources of water supplies, rainfall and runoff, present and probable future pop., indus. development, street and regional layout, geology, etc. Reliable contour maps often lacking, as are pptn. records which show max. rate in relation to time. Latter provided only by recording gages. Despite accomplishments in disposal and recovery of utilizable products from indus. wastes, much remains to be done and problem has been accentuated by war. Health authorities becoming more insistent on complete treatment of sewage and other wastes. In Canada, while there are 1300 water works systems, only 500 municipalities have sewerage systems and 115 sewage treatment plants, and of latter 40 afford primary treatment only. Hoped that financial arrangements for postwar constr. will recognize that provision of adequate sanitary facilities in some instances is beyond financial resources of municipalities.—*R. E. Thompson.*

Survey of Steel Water Tanks in 133 Canadian Municipalities. A. E. Berry. Can. Engr.—Wtr. & Sew. **82**: 10: 15 (Oct. '44). Extensive statistical data relating to use of steel water tanks in Canada given and discussed. Absence of elevated storage exceptional. Only 43 of systems here considered do not include steel storage tanks of some kind and 7 of these gravity supplies. Many of those without steel tank storage large centers, where consumption does not fluctuate as in smaller systems and where ground level storage readily provided. Included in survey are 32 standpipes and 53 elevated tanks. Most are covered. This is desirable to prevent contamn. by birds and growth of algae. One tank, at Kingston, Ont., in service 70 yr., and many in use 40 yr. or more. Remote control or other mech. devices for cutting tanks out of service during fires provided at only 16 plants. Manual closing of valves practiced at several. Slight or no corrosion reported in high proportion of cases and in nearly all instances no repairs or only minor ones found necessary. Some rivets replaced. Ice thicknesses of 1–2′ on sides of tanks common and in Montreal thicknesses of 7–8′ reported. Ice walls not only reduce capac. but also, when they become loose, score metal and hasten corrosion. Two methods of combating corrosion commonly employed—periodic cleaning and painting and cathodic protection. Cost of latter moderate. Frequency of painting varies widely—5 yr. common interval. Avg. cost of painting in 50 instances $555. Black commonly employed for interior and aluminum for exterior. Majority apply 2 coats. Scraping and wire-brushing usual methods of cleaning. Sand-blasting employed in some places. Some expenditure to improve appearance appears justified.—*R. E. Thompson.*

Increased Filtration Capacity for Ottawa, Ont. W. E. MacDonald. Wtr. & Sew. **83**: 2: 27 (Feb. '45). Plant capac. will be increased

from 35 to 42 mgd. by adding 2 filters to existing 10, provision having been made for this in original design. Most of installation will be undertaken by city water dept. Laterals for underdrains, of 4" centrifugal c-i. pipe, will be machined, drilled and tapped in civic workshop. Estd. cost **$85,000**. No storage other than 6-mil.gal. clear well available.—*R. E. Thompson.*

Co-operative Water Supply Scheme for Three Municipalities. C. R. HAGEY. Wtr. & Sew. **83**: 5: 24 (May '45). In '31, many wells in West Lorne, Ont., went dry but campaign to authorize constr. of public system unsuccessful. In '35, however, disastrous fire occurred and following year by-law approved. Extensive drilling failed to reveal ground water supply and plans then prepd. for supply from L. Erie that would eventually supply Rodney and Dutton also. Supply system, which cost **$130,000**, consists of 12" c-i. intake extending 1200' into 19' of water, low-lift pumping station at lake level and purif. plant at top of 100' embankment. Latter includes alum feeder, 4 octagonal-shaped spiral-flow mixing chambers (½-hr. detention), settling basin, 3 filters of 0.275-mgd. capac. each contg. 15" gravel and 26" sand, and 50,000-gal. clear well. Wash water provided by 1200-gpm. centrifugal pump. Cl applied before entering 5-mi. 10" main through which water pumped to village against pressure of 70,000-gal. elevated steel tank. Mains, totaling 5 mi., vary from 2" to 8" and services are of copper. Rodney and Dutton proceeding with distr. systems. Estd. cost of former **$110,000** and of latter **$130,000**. Rodney system includes 6 mi. of 6" main from West Lorne, 180,000-gal. standpipe and distr. grid of 4–8" c-i. pipe. Dutton system similar except that booster pump required in 7-mi. main from West Lorne. Both will pay 15¾¢ per 1000 gal. for all water over specified amt. at fixed price. Rates in West Lorne for residences **$2** per mo. and others will probably use this as std. Farmers along pipelines also supplied.—*R. E. Thompson.*

Water Works Improvements for the Town of Petrolia, Ont. G. GRAHAM REID. Wtr. & Sew. **83**: 2: 24 (Feb. '45). Water supply, since 1897, derived from L. Huron, 12 mi. distant, system consisting of 12" c-i. intake, pumping station at lake and main to town. During last 2 decades, difficulty in maint.g adequate supply and various addns. made, including coagulation basin at pumping station. Improvement program includes new 16" universal-jointed c-i. intake and low-lift pumping station, now under constr., and 2-mil.gal. storage reservoir and booster pumping station at town limits. Filtration plant (1.5 mgd.) proposed as postwar development. Improvements may postpone replacement of part of pipeline badly corroded by acid soil conditions.—*R. E. Thompson.*

New Water Works for Wallaceburg, Ont. ANON. Can. Engr.—Wtr. & Sew. **82**: 10: 22 (Oct. '44). To meet seasonal requirements of large canning plant, town (pop. 5100) embarked on program of water works constr. which will cost about **$180,000**. Estd. peak demand of canning plant 3 mgd. and 75% of total yearly demand will be used in month of Sept. Present water supply system, which consists of 12" intake pipe in River Chenal Ecarte 4 mi. west of town, 3 pressure filters and chlorination equip., inadequate and will be abandoned. In '43, avg. consumption 0.524 mgd., with peak delivery rate of 1 mgd. New plant will consist of intake in river nearer to canning plant, coagulation and settling tanks, gravity filters of 1-mgd. nominal capac. but capable of being operated at 1.33 mgd. for short periods, and high- and low-lift pumping stations. During spring, when flood water turbidity occurs, whole supply will be filtered; at other times, only domestic supply will be so treated and supply to canning plant will be chlorinated only, except for small amt. for drinking purposes. Pumps will be electrically driven, with several units equipped for alternate gasoline engine drive in case of power failure. Portable pumpers which can draw water either from Sydenham R. or hydrants will elim. necessity of raising pressure during fires. Intake and low- and high-pressure mains completed and new pumping equip. installed in temporary bldgs.—*R. E. Thompson.*

Gravenhurst's New Water Supply. W. B. REDFERN. Can. Engr.—Wtr. & Sew. **82**: 10: 25 (Oct. '44). Water supply for 35 yr. derived from Gull Lake, which has temp. of 70° in summer and is subject to taste and odor due to algae growths. Of alternate improvement programs, filtration or well supply, latter chosen after exploratory work. Two 70' gravel-wall wells, with 18" outer and 12" inner casings and bronze screens 12" in diam. and 10' long, will be constructed and equipped

with deep well pumps of 400-gpm. capac. Rock formations in vicinity largely granite and quartz; water hardness only 39 ppm. Alky. 14 and Cl^- 11 ppm., and water contains only trace Fe. Temp. 46°F. As water slightly acid, Calgon treatment may be advisable to prevent corrosion. Well pumps will deliver directly into distr. system against elevated tank at pressure, at ground level, of 70 psi. Covered concrete reservoir, from which existing fire pumps will take suction, will be built near Gull Lake pumping station. Capac. of supply system will be at least 1 mgd., 3 times present consumption. Estd. cost, exclusive of reservoir, $31,000, approx. what filter plant would have cost.—*R. E. Thompson.*

Three Years' Experience With Canada's Largest Municipal Water Softening Plant (Edmonton, Alta.). ROBERT G. WATSON. Can. Engr.—Wtr. & Sew. **82**: 2 (Jan. '44). Water supply derived from North Saskatchewan R., which originates some 315 mi. west of city in Saskatchewan glacier in Rocky Mts. Flow in summer may be as much as 60% of glacial origin and in late winter as little as 14%; hence great variations in chem. qual. occur, hardness ranging from 100 to 320, turbidity from 0 to 1800, and color from 0 to 215 ppm. Existing purif. plant remodeled for softening by excess lime-soda ash and 2-stage recarbonation, excess lime being required to reduce high Mg content. Water treated with softening reagents, alum, Cl and ammonium sulfate for sterilization, and, if required, activated C for taste and odor removal, and passed through mixing chambers equipped with mech. stirrers and Dorr clarifier fitted with revolving scraper. Part of sludge returned to raw water. Sufficient quicklime added to provide excess of 50–60 ppm. when soda ash being applied and 0–10 ppm. when soda ash not required. Clarifier effluent recarbonated with CO_2 generated by burning natural gas to give pH value of 9.4–9.9, and $CaCO_3$ formed removed by secondary settlement. Clear water again recarbonated to give pH value of 8.6–8.8 prior to filtration. During winter, plant receives condenser water from adjoining city power plant at temp. of approx. 62°F., which prevents freezing in open sedimentation basins and facilitates softening. Treated water hardness has avgd. 75 ppm. since Jan. 1, '41, when softening adopted. During '42 about 8 mgd. softened at cost of $21.92 per mil.gal. Lime dosage avgd. 172 and soda ash 233 ppm. Avg. hardness reduction 115 ppm.—*R. E. Thompson.*

Public Health Engineering in British Columbia. R. BOWERING. Can. Engr.—Wtr. & Sew. **83**: 10: 42 (Oct. '45). Now over 150 water systems, mostly publicly owned, serving more than 75% of pop. Supplies derived chiefly by gravity from mountainous streams and lakes. Considerable improvement in bact. qual. during past 2–3 yr., largely due to chlorination. Approx. 70% of pop. now use chlorinated water. One year's experience with chlorination in Vancouver shows marked reduction in bact. content without undue taste. Filter and chlorination plants needed in some municipalities. Relatively few sewage treatment plants, as main centers of pop. near salt water. Need for protection of bathing beaches may necessitate change in this situation.—*R. E. Thompson.*